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Handbook of Practical Hygiene

HANDBOOK

OF

PRACTICAL HYGIENE

BY

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PREFACE.

The lack of a convenient handbook for the guidance of students in the sanitary analysis of air, water, soil, and the principal food materials, and in testing the ventilation of buildings, is my apology for the preparation of this little work. There are several excellent handbooks in German that cover about the same field, as well as a number of general treatises on hygiene in English that contain some of the methods incorporated in this work, but there is no short and concise laboratory guide, in the English language, that satisfactorily meets the wants of the student in practical hygiene.

I have felt this want as a student and as an instructor and I trust, therefore, that this work may be a means of lightening the labor of others in this line of study.

As a general rule only the more simple and ready methods now in use have been here incorporated as it is expected that when once a good foundation for research has been laid the student will be stimulated to make use of the more extensive treatises relating to the subject.

The subject of food analysis has been gone into just far enough to permit of the detection of the more common forms of adulteration that are likely to be encountered, while the subject of general food analysis has been omitted entirely because, as a rule, medical students are not prepared to take up such a difficult subject in chemistry. For the same reason the subject of examination of clothing has been omitted.

Philadelphia, Pa., May 25, 1899.

CONTENTS.

	Page.
Introduction - - - -	I
Part I. Atmospheric air - - - -	6
Part II. Water - - - -	63
Part III. Soil - - - -	114
Part IV. Sanitary Analysis of Foods - -	125
Part V. Ventilation and Heating - -	150

INTRODUCTION

The practical hygiene of to-day is the logical outgrowth of observations in sanitary science as the result of the experiences of the peoples of different countries, cities, and towns. These observations were made chiefly during the present century since sanitary science had made very little progress from the empirical procedures of the ancients until these procedures had been tested through the means and measures afforded by modern chemistry and physics.

It will be of interest to trace briefly the more important steps in the development of sanitary science which gave rise to what is known as practical hygiene to-day, before taking up the various steps in the development of practical hygiene. The earlier discoveries which have been of immense value to sanitary science are those of Jenner with regard to vaccinia; those of Howard with regard to the relation of filth and insufficient air-supply to the high death-rate in prisons; those of Bowditch, of Boston, and Middleton, of England, with regard to the relation of dampness of the soil of a locality to the prevalence of tuberculosis; those of Gerhard, of Philadelphia, with regard to the differentiation between typhus and typhoid fever; and those of von Pettenkofer, of Munich, with regard to the relation of ground-water to the prevalence of typhoid and cholera.

The discovery of the etiological factors in infectious diseases, the definite determination of the relation of certain diseases to polluted water-supplies, and of the

intimate relation of certain respiratory diseases with the ventilation and general sanitary condition of buildings, mark the beginning of the practical application of scientific methods to sanitary science. Practically all of these discoveries have been made within the last two or three decades. The influence of the several sanitary commissions of England, as the Health of Towns Commission, the Barracks Commission, and the Rivers Pollution Commissions, in stimulating investigations and in the collection of valuable data, has been very great.

The discoveries made during this period which stand out prominently and mark important steps in the development of practical hygiene, are those of Pasteur, of Paris, and of Koch, of Berlin, upon the relation of micro-organisms to disease; those of Lister upon the aseptic treatment of wounds; the experiments of Paul Bert on the influence upon life and health of various atmospheric conditions; those of von Pettenkofer and Voit on expired air, and the latter's accurate methods for the determination of carbon dioxid in air.

Of the discoveries and adaptations of methods employed in chemistry and physics to sanitary science which mark the rise of practical hygiene, it is impossible to speak with any great definiteness, since the advancement has been so gradual that it would be difficult to trace out the various steps in order to make special mention of them. Several of these methods, however, stand out quite prominently, in addition to those already mentioned, so that it is possible to

trace their birth and evolution. Among others the following should receive special mention: The method for the determination of organic matter in water by means of potassium permanganate, published by Forchhammer, of Copenhagen, in 1849, and modified since by Kubel and by Tiemann, and others; the method for the determination of the hardness of water by means of an alcoholic solution of soap, published by Mm. Boutron and Felix Boudet in *Comptes rendus*, March 26, 1855, and elaborated by Dr. Thomas Clark, of Aberdeen; the perfection of Levöl's method of determining chlorin, by Mohr, in 1856, by the use of potassium chromate solution as indicator and the application of the method to the determination of chlorin in water; the discovery of a delicate reagent for the detection of ammonia, by Nessler, in 1856; the method for the determination of the nitrogenous organic matter in water as free and albuminoid ammonia, published by Wanklyn, Chapman, and Smith before the Chemical Society, of London, June 20, 1867; the discovery of a satisfactory method for the determination of nitrogen as nitrites in water, by Griess, in 1881, and its improvement by Warrington; the discovery of a delicate test for nitrates in water, by Grandval and Lajoux, in 1885. The methods in use for the determination of organic matter in air had their origin in the ingenuity of Augus Smith, Chapman, Moss, and Remsen.

The evolution of practical hygiene has been very rapid during the last two or three decades, so much so that the student of to-day rarely realizes how recently all of the different methods employed in the

analysis of water have come into use. If we go back to the year 1855 we find that the only chemical methods known by means of which organic contamination of water could be detected were : Loss on ignition ; Forchhammer's permanganate test ; the distillation of enormous quantities of water, as much as 50 gallons, in order to estimate the ammonia, which was done by titration with standard acid. This procedure has long since been very much simplified through the introduction of the Nessler process and the Wanklyn method of distillation. The development of practical hygiene has been of such recent date that so far it has failed to receive the consideration in educational institutions which it really merits from its immense practical utility.

The opinion that the medicine of the future must be largely preventive medicine is rapidly gaining ground, consequently the study and application of all the preventive measures known becomes of the greatest importance in the training of medical men.

Since pure air, pure water and food, and sanitary habitations and environment are of primary importance in the maintenance and restoration of health, the study of the character and sources of impurities in these, of whatever nature, is highly essential in the practical training of the physician of to-day.

The testimony of experts before recent sessions of government and legislative investigation commissions, has shown that food adulterations of a character which is as yet practically unknown to the general public are becoming quite frequent. Such disclosures as

those made by Dr. Wiley, chief chemist of the Department of Agriculture, before the Senatorial Pure Food Investigation Committee, in which he stated that articles of food were imported from abroad, adulterated to such a degree that they would not be used in the countries where they were produced, should arouse us to more active supervision of the character of the food materials exposed for sale in our markets. While many of the adulterations specified in the testimony before these investigation commissions are not necessarily dangerous or even injurious to health, they are nevertheless fraudulent and should not be tolerated under any circumstances. On the other hand the use of highly injurious food preservatives is far from uncommon and is rarely suspected. Some of these preservatives act in such a manner as to render the food practically indigestible aside from any injurious effect which they may exert upon the digestive organs themselves. In order to properly control the healthfulness of food supplies it is necessary to have more general investigation into the nature and composition of the different food materials offered for sale in the markets. In order to make such a supervision feasible it is necessary to have a considerable force of trained analysts in all the larger cities and towns, in addition to a more general supervision of the mode of preparation and system of marketing of the different forms of prepared foods. In this manner it would be possible to protect the common people, at least more effectually than is done at present, against gross fraud and against injury to health from adulterated food.

PART I

ATMOSPHERIC AIR

The air, when pure, is composed of 20.99 per cent. by volume of oxygen, 0.03 to 0.04 per cent. of carbon dioxid, about 78 per cent. of nitrogen, 1.0 per cent. of argon, and varying proportions of watery vapor. Traces of ammonia and organic vapors are also generally present. The relative proportion of the two principal gases, oxygen and nitrogen, remains quite constant in all portions of the globe, while the carbon dioxid, aqueous and organic vapors, and the ammonia vary quite perceptibly in different localities and under various modifying influences.

For the hygienist, therefore, the constituents of the atmosphere which vary in their relative proportions, the carbon dioxid, aqueous and organic vapors, and ammonia, are of primary interest. It is these constituents, along with the temperature, barometric pressure, and the force and direction of the wind, that will engage our attention.

The nitrogen serves merely as a diluent for the oxygen of the air, and, so far as known, has no other influence upon man. The amount of aqueous vapor in the air of dwellings is a most important factor in relation to the comfort and health of the occupants.

CHAPTER I. PHYSICAL EXAMINATION OF AIR-METEOROLOGY

A. OBSERVATION OF TEMPERATURE—THERMOMETERS

The observation of temperature in the laboratory is commonly made by means of a mercurial thermometer.

a. Control of the zero-point.—The zero-point of a mercurial thermometer should be verified from time to time, and all new thermometers must be verified before they are brought into use, to avoid any error from variations which are liable to take place as the result of contraction of the glass bulb.

Process.—The verification of the zero-point of a thermometer is made by placing the bulb into a small glass funnel filled with cracked ice, when, if the thermometer is properly constructed, it will register 0° C. in about five minutes.

b. Testing the boiling-point of water as registered by a thermometer.—The thermometer is placed in a so-called hypsometer, in which it is quite surrounded with streaming steam, so that only the upper part of the scale is visible outside of the apparatus.

The water in the apparatus is boiled for ten minutes and then the reading of the thermometer is taken. It is to be remembered that the boiling-point of water is influenced by the barometric pressure—the greater the pressure the higher the boiling-point of water, and *vice versa*. For instance a correct centigrade thermometer will indicate 100° C. only when the baromet-

ric pressure at 0° C. is 760 mm. Consequently it is necessary to observe, at the time of reading the thermometer, the barometric pressure and the temperature at the barometer. The observed barometric pressure must then be corrected for 0° C., according to the formula, $b_o = \frac{b_t}{1 + a.t}$ where a = the coefficient of expansion for mercury for each degree of temperature, or 0.00018.

The normal boiling-point for the corrected barometric pressure is then taken from Regnault's table (see Table I) and if this coincides with the boiling-point as indicated by the thermometer that is being tested, then the latter is correct, otherwise the difference is to be noted as the correction for the boiling-point.

Example.—A new thermometer registers the boiling-point at 98.2° C., with the barometric pressure at 713 mm., and the temperature at the barometer 15° C. The barometric reading is reduced to 0° C. according to the formula

$$b_o = \frac{b_t}{1 + a.t} = 711.08 \text{ mm.}$$

According to the table the temperature of boiling water at 711 mm. = 98.15° C., and at 712 mm. = 98.19° C. Difference = 0.04° for 1° of temperature, and for 0.01° the difference is 0.0004° , and for 0.08° it is 0.0032° , hence the temperature of boiling water at 711.08 mm. = 98.1532° C. Since our thermometer registered 98.2° C. it registers 0.0468° too high, and the correction for the boiling-point is 0.0468° .

Testing the accuracy of the thermometer between the two fundamental points:

The accuracy of the scale between the zero- and

boiling-point is determined by comparison with a normal thermometer. This is done by placing both in a wooden vessel containing distilled water and gradually raising the temperature of the water. The two thermometers must be placed at equal distances from the sides and bottom of the vessel. At intervals of several degrees the reading is taken of each thermometer. In case there is a difference between the readings of the thermometers between two points another observation should be made about half way between those points, or one proceeds as follows: It has been found, for instance, that the thermometer to be tested varies from the normal thermometer $+0.1^{\circ}$ at 10° , and at 20° it varies $+0.4^{\circ}$. Undoubtedly the thermometer changes between 10° and 20° . We may assume that the degree of variation is evenly distributed between the two points, and there are points at which the correction is 0.2° and 0.3° . These points may be determined by calculation by dividing the space between 10° and 20° into four parts of 2.5° each; after each 2.5° the correction changes by 0.1° .

The correction	0.1°	reaches from	10.0°	to	12.5°
"	"	"	"	"	"
"	0.2°	"	"	"	15.0°
"	0.3°	"	"	"	17.5°
"	0.4°	"	"	"	20.0°

For these corrections, however, such great differences in temperature, as 10° to 20° , should not be used, but a reading should be made at least once between the two points—preferably at 15° —or better still at each degree of the scale.

TABLE I.

Regnault's Table Showing the Boiling-point of Water according to the Degree of Barometric Pressure.

Barom-eter.	Temper-ature.	Barom-eter.	Temper-ature.	Barom-eter.	Temper-ature.
580	92.6	650	95.7	715	98.3
585	92.8	655	95.9	720	98.5
590	93.1	660	96.1	725	98.7
595	93.3	665	96.3	730	98.9
600	93.5	670	96.5	735	99.1
605	93.7	675	96.7	740	99.3
610	94.0	680	96.9	745	99.4
615	94.2	685	97.1	750	99.6
620	94.4	690	97.3	755	99.8
625	94.6	695	97.5	760	100.0
630	94.8	700	97.7	765	100.2
635	95.1	705	97.9	770	100.4
640	95.3	710	98.1	775	100.5
645	95.5				

B. SPECIAL THERMOMETERS

1. **Spirit thermometer.**—For temperatures below 0° C.—especially below -20° C.—a spirit thermometer is used. These are similar in construction to the ordinary mercurial thermometer but contain alcohol colored with some anilin dye, usually eosin, as the thermometric fluid.

2. **Thermometers for high temperatures.**—For the observation of temperatures over 100° C. a long-stemmed mercurial thermometer is used. In this manner the scale may be lengthened so as to register up to 300° C. For temperatures ranging from 300° to 450° C. the capillary tube of the thermometer contains nitrogen gas instead of a partial or complete

vacuum. In this manner the mercury is prevented from boiling by the increased pressure within the capillary tube. At still higher temperatures air thermometers are used, air being the thermometric substance.

3. Pyrometer.—Pyrometers are constructed of a bar of metal or graphite which is fastened to a support at one extremity. Variations in temperature bring about alterations in the length of this bar and these changes are measured by means of a movable pointer attached to the free end of the bar in such a manner that the temperature is indicated on a fixed scale over which the pointer moves. These instruments are graduated by making comparative observations with an air thermometer. The pyrometers are less accurate than the air thermometers for the observation of high temperatures.

4. Thermograph.—By means of mechanical or electrical devices the variations in the temperature curve, as indicated by the pointer of the pyrometer, are recorded on a revolving chart having appropriate rulings for different degrees of temperature and also for definite periods of time, as a day, a week, or a month. By means of a pen or small piece of graphite attached to the tip of the pointer, a permanent record of its to-and-fro movements, under the influence of fluctuations in the temperature, is produced.

5. Maximum-minimum thermometer.—These instruments record both the highest and the lowest

points reached by the temperature during a definite period of time, as twenty-four hours. The form of instrument in common use is that of Six, consisting of a U-shaped, capillary glass tube, the upper portions of both arms being of somewhat larger caliber than the body of the tube. A thermometer scale is attached to each arm of the tube, the one arm forming the maximum, the other the minimum, thermometer. The upper portion of the arm corresponding to the maximum thermometer is expanded into a small, pointed bulb and contains a little alcohol and vapor of alcohol. The lower portion or body of the tube contains mercury. In addition to this each arm also contains an index consisting of a small, barbed bar of steel, one end of which rests on the surface of the column of mercury forming the two thermometers. The thermometric substance in this instrument is the alcohol in the upper arm of the tube, while the mercury in the body of the tube is the propeller of the indices. Both indices are carried upward by the contraction on the one hand, and the expansion on the other, of the mercurial column as the result of a fall or rise in the temperature, and each of them is arrested at the point corresponding to the lowest temperature reached during the period of time under observation in the one case, and at the point corresponding to the highest temperature reached during the same time on the other hand, thus recording the two extremes in temperature for that period of time. The indices are prevented from falling with the receding column of mercury by the feathery projections along their sides.

After reading the thermometers the indices are again brought in contact with the surface of the mercurial column by drawing a small horseshoe magnet downward along the side of each arm of the instrument.

6. Measurement of solar radiation.—The ordinary mercurial thermometer indicates only the heat communicated to it by the surrounding media and is but little influenced by the heat radiating from the sun directly. To measure the amount of heat radiating from the sun a maximum thermometer, with blackened bulb, is commonly employed. This instrument is enclosed in a larger glass tube exhausted of air, one end of which is expanded into a bulb. The bulb of this thermometer is influenced by the solar radiations alone, reflecting the solar heat against the outer bulb whose temperature is the same as that of the surrounding atmosphere. The instrument is placed in a horizontal position and registers higher than one that is exposed to the air, the increase in temperature indicating the amount of heat radiating from the sun.

7. Terrestrial radiation.—For the purpose of measuring the radiation of heat from the earth at night a minimum thermometer is placed in a horizontal position, on wooden supports, in an exposed place. The reading of this thermometer is compared with that of another minimum thermometer at the same place, but protected from such influence; a higher reading of the latter indicates the amount of heat radiating from the earth.

C. THERMOMETER SCALES

1. **The centigrade scale.**—The centigrade scale is the one most commonly used in scientific investigations. It has for its zero-point the melting-point of ice, while 100° represents the boiling-point of water with the barometer at 760 mm.

2. **The Fahrenheit scale.**—In this scale the zero-point is 32° below the melting-point of ice, and the boiling-point of water is at 212° with the barometer at 29.905 inches in the latitude of London. This is the standard scale in the United States, but, for obvious reasons, the centigrade scale is preferable to it.

3. **The Reaumur scale.**—In this scale the melting-point of ice also corresponds to the zero-point, while the boiling-point of water is at 80° . This scale has never been used very extensively and is now falling into disuse.

4. **Relative values of the degrees on the three scales.**—

$$5^{\circ} \text{ C.} = 9^{\circ} \text{ F.} = 4^{\circ} \text{ R.}$$

$$1^{\circ} \text{ C.} = \frac{9}{5}^{\circ} \text{ F.} = \frac{4}{5}^{\circ} \text{ R.}$$

$$1^{\circ} \text{ F.} = \frac{5}{9}^{\circ} \text{ C.} = \frac{4}{9}^{\circ} \text{ R.}$$

$$1^{\circ} \text{ R.} = \frac{5}{4}^{\circ} \text{ C.} = \frac{9}{4}^{\circ} \text{ F.}$$

To convert centigrade degrees into Fahrenheit degrees, multiply by $\frac{9}{5}$ and add 32. $(\text{C.} \times \frac{9}{5}) + 32 = \text{F.}$

To convert centigrade degrees into Réaumur degrees, multiply by $\frac{4}{5}$. $C. \times \frac{4}{5} = R.$

To convert Fahrenheit degrees into centigrade degrees, subtract 32, and multiply by $\frac{5}{9}$. $(F. - 32) \times \frac{5}{9} = C.$

To convert Fahrenheit degrees into Réaumur degrees, subtract 32, and multiply by $\frac{4}{9}$. $(F. - 32) \times \frac{4}{9} = R.$

To convert Réaumur degrees into centigrade degrees, multiply by $\frac{5}{4}$. $R. \times \frac{5}{4} = C.$

To convert Réaumur degrees into Fahrenheit degrees, multiply by $\frac{9}{4}$ and add 32. $(R. \times \frac{9}{4}) + 32 = F.$

D. ATMOSPHERIC PRESSURE

The atmosphere having weight exerts, therefore, a constant but variable amount of pressure upon the earth's surface. The amount of pressure exerted by the atmosphere is dependent upon the quantity of moisture it is holding and upon its temperature. The degree of pressure which it exerts is subject to constant fluctuations through the incessant movements occurring between its higher and lower strata, as well as through its movements from one point to another over the earth's surface, the latter movements giving rise to what are known as winds. The movements of the atmosphere are produced by an increase or a decrease in the amount of moisture at one point of the earth's surface as compared with other surrounding points, such increase or decrease in the amount of moisture being brought about through precipitation

from the clouds, or through evaporation of moisture from the earth's surface. On the other hand movements of the atmosphere are also brought about by an increase or decrease in its temperature as the result of a greater amount of heat radiation at one point than at another, but more particularly through the influence of the high temperature of the torrid zone and the influence of the low temperature of the polar regions.

The barometer is high (*a*) when the air is cold, because it is then more dense than it is when warm; (*b*) when the air is dry, because it is then also more dense than when it is moist; (*c*) when an upward current sets in towards a certain point, because in consequence of this movement, the lower strata are compressed.

The barometer is low (*a*) when the lower strata are heated there is an upward movement, as the density of these strata decreases, and the upper or lighter strata are displaced laterally; (*b*) when the air is damp, because the density of aqueous vapor, at 760 mm. and 0° C. is 0.622, air being 1, therefore the mixture becomes lighter the more moisture it contains; (*c*) when the air has a gradual upward movement without a simultaneous lateral movement to replace the air that is moving upward.

As the density of the atmosphere influences the amount of pressure which it is capable of exerting it is evident that the pressure must bear an inverse relation to the altitude; the higher the altitude the greater the rarification of the air and, consequently, the higher the barometer. On the other hand the density of the air increases as we descend to the level of the sea, or

penetrate into the interior of the earth, and the barometric reading is lower, being at 760 mm. at the sea-level, and gradually falling as we descend below that level.

1. Mercurial Barometers

a. **Cistern barometer.**—Observations of barometric pressure are commonly made with the cistern barometer. It consists of a glass tube, 80 cm. in length, sealed at one end. This is filled with mercury and inverted in a small metal cistern containing mercury, when a portion of the mercury in the tube escapes, leaving a vacuum in the upper part of the tube. The greater portion of the mercury in the tube is retained through the pressure exerted on the surface of the mercury in the cistern by the atmosphere. The top of the cistern is partly closed in and has a small ivory point projecting from the roof which serves as the zero-point of the scale, and is called the “fiducial point.” The bottom of the cistern is composed of leather and can be raised or lowered as required, so that the surface of the mercury is always brought in contact with the ivory point projecting from the roof. In this manner the zero-point of the scale is regulated at each reading. The barometer tube is enclosed in a metal tube having a ring attached to its upper extremity from which it is suspended. It must hang perpendicularly, but is prevented from swinging by means of four small screws projecting from the inner surface of the metal ring surrounding the cistern. These screws are adjusted in such a manner that they

prevent any marked swinging of the instrument, and yet avoid communicating the influence of any jarring from the supports to which it is attached.

The barometer scale.—For scientific observations the metric scale is most commonly employed. In this scale the standard pressure at sea-level is taken as 760 mm., with the temperature at 0° C. In the standards of the United States and Great Britain measurement is made in inches, tenths, and hundredths, with the temperature at 32° F. The standard pressure at sea-level is 30 inches.

The vernier.—In order to facilitate the accurate reading of the barometer, a small movable scale, called a "vernier," is attached at the side of the fixed scale, and is moved upward and downward by means of a rack-and-pinion arrangement. This allows the reading of the fractional parts of the millimeter.¹

To read the fractional parts of a millimeter of the pressure recorded by the barometer, the zero-point of the vernier is brought on a level with the top of the meniscus of the column of mercury in the barometer tube—to the point at which it cuts off the light passing between it and the top of the meniscus. The line on the vernier scale that is on a level with, or nearest to, one of the lines on the fixed scale indicates the number of tenths of a millimeter to be added to the

¹ The principle of the vernier is this, that a given length containing n divisions of the fixed scale is divided into $n + 1$ divisions on the vernier; usually representing the length of one millimeter on the fixed scale.

reading of the fixed scale; *e. g.*, the reading of the fixed scale is 764 mm., and the line on the vernier scale that is on the same level with, or nearest to, one of the lines on the fixed scale is the eighth, then the correct reading of the barometer is 764.8 mm.

Temperature at the barometer.—Attached to the metal case surrounding the barometer tube is a small mercurial thermometer which records the temperature at the barometer. The reading of this thermometer should always be taken before reading the barometer itself, otherwise the breath of the observer and the heat given off from his body might change its reading, and thus affect the accuracy of his observations.

Manner and place of hanging a barometer.—Barometers should be hung in a room protected from direct sunlight and removed from marked temperature fluctuations.

Reading of the barometer.—The first point to be observed in reading the barometer is to note and record the temperature at the thermometer attached to it. The next point to observe is whether the instrument is properly suspended, after which the zero-point of the scale is adjusted by bringing the surface of the mercury in the cistern to the "fiducial point," by either raising or lowering the bottom of the cistern, as may be required, by means of the screw attached beneath it. The vernier is now raised above the top of the column of mercury in the tube and then carefully brought down on a level with the top of the meniscus. In regulating the vernier it is very essential that the eye of the observer is also on a level with the top of

the meniscus. The number of millimeters' pressure is shown on the fixed scale and the tenths of a millimeter on the vernier scale.

Corrections of barometric readings.—To obtain accurate results, as well as for purposes of comparison, several corrections of the readings of the barometer are necessary: (*a*) for variations in the meniscus according to the diameter of the barometer tube. For a tube of 12 mm. diameter the correction is so small that it has but little influence on the results and may be ignored. For the same reasons (*b*) variations in the barometer scale, as well as (*c*) variations in the glass tube under different conditions, may be ignored. The only important influence on the barometric reading for which correction must be made is that which is due to the expansion and contraction of the mercury at different degrees of temperature. With an increase of 1° C. of temperature, mercury expands at the rate of 0.00018 times its volume, consequently the influence of varying degrees of heat on the height of the column of mercury in the barometer tube must be eliminated from every observation. Correction of the barometric reading for temperature is made according to the formula: $b/o = \frac{b/t}{1 + at}$, reducing the reading to 0° C. temperature.

b/o = the barometer reduced to 0° C.,

b/t = " " as read,

a = " constant, 0.00018, the coefficient of expansion of mercury for each degree of temperature.

t = " temperature at the barometer.

Example.—The barometer stands at 768.4 mm., with the temperature at 18.3° C. Then

$$b/o = \frac{768.4}{1 + 0.00018 \times 18.3}$$

or $b/o = 765.8$ mm.

With the temperature below 0° C. the formula is

$$b/o = \frac{b/t}{1 - a.t.}$$

b. Stationary barometer.—In the stationary barometer the bottom of the cistern is fixed and the zero-point of the scale cannot be adjusted at each reading as in the cistern barometer. The scale is also fixed, but it is arranged in such a manner, however, that its zero-point indicates a barometric pressure of 760 mm.

c. Differential barometer.—This form of barometer consists of a glass tube, of equal diameter throughout, and which is bent in the form of the letter S. It is sealed at its upper end, but the lower arm of the tube, which is U-shaped, is open to the air. The tube is somewhat constricted at the middle whereby the movement of the mercury is impeded, to a slight degree. The upper portion of the tube contains a vacuum, hence the contraction and expansion of the mercury lowers and raises the level of the column in both arms of the tube. The scale is either fixed or movable, the method of reading the barometer depending on this point. The distance between the upper and lower levels of the mercury is the height of the mercurial column. This form of barometer is used principally in determining degrees of altitude and the height of mountains.

2. Aneroid Barometer

The aneroid barometer consists of a thin-walled, metallic chamber which has been nearly exhausted of air, its sides being held apart by a strong spring. The pressure of the atmosphere on the sides of the chamber is indicated by means of a pointer which is attached to the spring and moves over a dial. Aneroid barometers are also so constructed as to be self-registering—like the thermograph.

Correction of the readings.—Three corrections of the aneroid barometer are necessary: (*a*) for temperature, (*b*) for the divisions on the dial, and (*c*) for the altitude of the place of observation. For each instrument these factors must be ascertained, for the location in which it is to be used, by comparison with a mercurial barometer.

E. HUMIDITY OF THE ATMOSPHERE

At different temperatures air is capable of taking up variable amounts of moisture, there being a saturation point for each degree of temperature. The point of saturation rises with the elevation of the temperature of the air, so that when the air is saturated at a high temperature and is then cooled, there is a precipitation of moisture in the form of rain or dew, or in the form of sleet, snow, or hail.

a. Dew-point.—The point of saturation at a certain degree of temperature is known as the dew-point.

b. Absolute humidity.—The absolute humidity denotes the amount of moisture, in grams, which 1 cubic

meter of air, of a certain temperature, may be holding. The absolute humidity varies with the temperature, increasing in amount with increase of the temperature of the air.

c. Maximum of saturation.—The maximum saturation of air is the maximum amount of moisture, in grams, which 1 cubic meter of air, at a certain temperature, is capable of holding.

d. Deficiency of saturation.—Deficiency of saturation denotes the amount of moisture, in grams, which 1 cubic meter of air, at a certain temperature, is capable of taking up, in addition to that which it already contains, to become fully saturated. It is the difference between the maximum saturation for that degree of temperature and the absolute humidity.

e. Relative humidity.—The relative humidity denotes the quantity of moisture contained in the air, at a certain temperature, expressed in per cent. of the quantity of moisture that can be taken up at that temperature, or the absolute humidity expressed in per cent. of the maximum of saturation. It is the greatest near the surface of the earth during night when the temperature approaches the dew-point, and it is least during the middle of the day when the heat is greatest.

F. ESTIMATION OF MOISTURE IN THE AIR

1. Direct hygrometers.—There are three forms of direct hygrometer all depending on the same principle: (a) Daniell's, (b) Regnault's, an improved form of

Daniell's instrument, and (c) Dines's. *Daniell's hygrometer* consists of two glass bulbs connected by a glass tube bent twice at right angles. The instrument is attached to a small wooden stand to which is fixed a small mercurial thermometer. One of the bulbs is made of black glass and contains a thermometer; the other bulb is made of ordinary glass and is covered with muslin. The bulbs contain some ether vapor. By holding the covered bulb in the hand for a minute, the ether contained in it evaporates and passes over into the black bulb; some ether is then dropped on the muslin, and, by its rapid evaporation, reduces the temperature of this bulb, causing the ether vapor in the black bulb to contract and distil over into the other bulb. The temperature of the black bulb is now reduced until the dew-point is reached and the moisture in the air surrounding it is deposited on the shining black bulb. The instant this occurs the temperature shown by the thermometer inside the bulb is noted (the dew-point), as well as the temperature of the air as shown by the thermometer on the stand.

Regnault's hygrometer is an improvement on Daniell's, having a bright silver cup in place of a glass bulb to contain the ether, and the ether is evaporated by means of an aspirator or air-pump attached to the cup.

Dines's hygrometer consists of a vessel, containing ice-cold water, and a black glass attached to a wooden stand. The vessel containing the ice-cold water has a tube attached that connects it with a small, closed chamber underneath the glass plate, so that the water

passing into this chamber cools the bulb of a thermometer within the chamber, just beneath the glass plate. The flow of water is controlled by means of a stop-cock. At the moment when dew begins to deposit on the glass plate the temperature at the thermometer, attached to the instrument, is noted, the air temperature being noted at the same time.

2. Indirect hygrometers.—There are two principal kinds of indirect hygrometer: (*a*) the hair hygrometer, and (*b*) the wet- and dry-bulb thermometer.

The hair hygrometer, of Wolpert, consists of a human or horse hair that has been freed from oily matter, one end of which is fixed, while a light weight is suspended from the other end. A portion of the hair passes over a pulley to which is attached a pointer that moves over a scale and indicates the relative humidity of the air in per cent. of saturation. The scale of each instrument is graduated by wetting the hair to complete saturation and marking the point 100° , then placing the instrument over sulphuric acid of known strength and marking the point indicated 15° of saturation. The intervening space is divided into eighty-five equal parts, each of which denotes a "degree of relative humidity."

The wet- and dry-bulb thermometer, or psychrometer.—This consists of two ordinary mercurial thermometers, as nearly alike as possible, and registering tenths of a degree centigrade, which are attached to a small frame or to a strip of wood. The bulb of one of the thermometers is covered with a jacket of cotton threads

which extend into a small cup of water attached to the bottom of the frame of the instrument, thus keeping the bulb continuously moist through capillary attraction. This is known as the "wet-bulb" and the other as the "dry-bulb" thermometer.

As long as the atmosphere is not saturated, moisture continues to evaporate from the wet-bulb and, in consequence, the mercury cools and contracts and shows a lower temperature than the dry-bulb thermometer, which registers the temperature of the surrounding atmosphere. The difference between the temperature registered by the two thermometers is greatest when the atmosphere contains the least moisture, and when it is saturated they show the same temperature, since there is no evaporation from the wet bulb. When the temperature is below freezing capillary action ceases and the readings of the wet-bulb thermometer are unreliable.

A form of this instrument that is in common use is the "sling" psychrometer. The two thermometers are fastened on opposite sides of a small strip of wood, having a handle attached to its upper end by means of which the instrument can be made to revolve. The wet-bulb thermometer projects three or four cm. beyond the lower end of the wooden support, and the jacket surrounding it is thoroughly moistened with distilled water whenever an observation is to be made.

Information derived from hygrometer observations.

—The important items of information to be derived from hygrometer observations are: (a) the dew-point, (b) the tension of aqueous vapor, or the absolute hu-

midity, and (*c*) the relative humidity of the atmosphere. Each of these may be calculated from the difference between the temperature of the wet- and dry-bulb thermometers, either by formulae, or from tables. The dew-point of the atmosphere is determined directly by means of one of the three forms of direct hygrometers.

The absolute humidity can be calculated from the readings of the wet- and dry-bulb thermometers according to the formula: $m = M - cd$, where m = the absolute humidity of the air at the temperature indicated by the dry-bulb thermometer, t , and M = the maximum of saturation at the temperature of the wet-bulb thermometer, f , which is found by reference to Flüggé's table (see Table II).

c = a constant, usually 0.65, but in the winter, when the bulb is covered with ice, 0.56, and

d = the difference between the wet- and dry-bulb thermometer readings.

The product cd can also be taken directly from the table.

TABLE II.

Table of the Water Capacity of Air at Different Temperatures. (From Emmerich and Trillich.)

Temp. of the Air.	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
— 20	1.06	....	....	....	....	....	....	....	....	....
— 15	1.57	....	....	....	....	....	....	....	....	....
— 14	1.70	1.69	1.68	1.67	1.66	1.64	1.62	1.61	1.60	1.58
— 13	1.84	1.82	1.81	1.80	1.78	1.77	1.76	1.74	1.73	1.71
— 12	1.97	1.96	1.95	1.94	1.93	1.91	1.90	1.89	1.87	1.85
— 11	2.13	2.10	2.08	2.07	2.05	2.04	2.03	2.01	2.00	1.98
— 10	2.30	2.28	2.27	2.25	2.23	2.21	2.20	2.18	2.16	2.15
— 9	2.49	2.47	2.45	2.43	2.41	2.39	2.38	2.36	2.34	2.32
— 8	2.67	2.65	2.63	2.62	2.60	2.58	2.56	2.54	2.53	2.51
— 7	2.88	2.86	2.84	2.82	2.80	2.77	2.75	2.73	2.71	2.69
— 6	3.11	3.09	3.06	3.04	3.02	2.99	2.97	2.95	2.93	2.90
— 5	3.36	3.33	3.31	3.28	3.26	3.23	3.21	3.18	3.16	3.13
— 4	3.61	3.58	3.56	3.53	3.51	3.48	3.46	3.43	3.41	3.38
— 3	3.90	3.87	3.84	3.81	3.78	3.75	3.73	3.70	3.67	3.64
— 2	4.19	4.16	4.13	4.10	4.07	4.05	4.02	3.99	3.96	3.93
— 1	4.52	4.49	4.45	4.42	4.39	4.35	4.32	3.29	4.26	4.22
0	4.87	4.83	4.80	4.76	4.73	5.69	4.66	4.62	4.59	4.55
+ 1	5.21	5.25	5.28	5.32	5.35	5.39	5.43	5.46	5.50	5.53
2	5.57	5.61	5.65	5.69	5.73	5.76	5.80	5.84	5.88	5.92
3	5.96	6.00	6.04	6.08	6.12	6.16	6.21	6.25	6.29	6.33
4	6.37	6.41	6.45	6.50	6.54	6.58	6.62	6.66	6.71	6.75
5	6.79	6.84	6.88	6.93	6.98	7.02	7.07	7.11	7.16	7.21
6	7.26	7.31	7.35	7.40	7.45	7.49	7.54	7.59	7.64	7.68
7	7.73	7.78	7.83	7.89	7.94	7.99	8.04	8.09	8.15	8.20
8	8.25	8.30	8.36	8.41	8.47	8.52	8.57	8.63	8.68	8.73
9	8.79	8.85	8.91	8.96	9.02	9.07	9.13	9.19	9.24	9.30
10	9.37	9.43	9.49	9.55	9.61	9.67	9.74	9.80	9.86	9.92
11	9.98	10.04	10.11	10.17	10.24	10.30	10.36	10.43	10.49	10.56
12	10.62	10.69	10.75	10.82	10.88	10.95	11.02	11.08	11.15	11.21
13	11.28	11.35	11.43	11.50	11.58	11.65	11.72	11.80	11.87	11.95
14	12.02	12.09	12.17	12.24	12.32	12.39	12.46	12.54	12.61	12.69
15	12.76	12.84	12.92	13.00	13.08	13.15	13.23	13.31	13.39	13.47
16	13.54	13.63	13.72	13.80	13.89	13.97	14.05	14.14	14.22	14.31

Temp. of the Air.	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
17	14.39	14.48	14.58	14.67	14.77	14.86	14.95	15.05	15.14	15.24
18	15.33	15.42	15.50	15.59	15.68	15.76	15.85	15.94	16.03	16.11
19	16.20	16.39	16.44	16.49	16.58	16.68	16.78	16.87	16.97	17.06
20	17.16	17.26	17.37	17.47	17.58	17.68	17.78	17.89	17.99	18.10
21	18.20	18.31	18.41	18.52	18.63	18.73	18.84	18.95	19.06	19.17
22	19.29	19.41	19.52	19.64	19.75	19.87	19.99	20.10	20.22	20.33
23	20.45	20.56	20.68	20.79	20.91	21.02	21.14	21.25	21.37	21.48
24	21.60	21.73	21.85	21.98	22.11	22.23	22.36	22.49	22.62	22.74
25	22.87	23.00	23.13	23.27	23.40	23.53	23.66	23.79	23.93	24.06
26	24.19	24.33	24.47	24.61	24.75	24.88	25.02	25.16	25.30	55.44
27	25.58	25.72	25.86	26.01	26.15	26.29	26.43	26.57	26.72	26.86
28	27.00	27.15	27.31	27.46	27.61	27.76	27.92	28.07	28.22	28.38
29	28.53	28.69	28.85	29.01	29.17	29.33	29.50	29.66	29.82	29.98
30	30.14	30.31	30.47	30.64	30.81	30.97	31.14	31.31	31.48	31.64
31	31.81	31.98	32.16	32.33	32.51	32.67	32.86	33.03	33.21	33.38
32	33.56	33.74	33.92	34.10	34.28	34.45	34.63	34.81	34.99	35.17
33	35.35	35.54	35.73	35.93	36.12	36.31	36.50	36.69	36.87	37.08
34	37.27	....	....	....	....	....	....	....	....	....

The constant c varies indirectly according to the barometric pressure and the air-movement, but, for hygienic purposes, it is not necessary to make corrections because the slight difference between the results obtained with the above formula, and those obtained by taking into consideration the influence of barometric pressure, are of no vital importance.

Process.—Temperature at the dry-bulb thermometer
(t) = 32.5° C.

Temperature at the wet-bulb thermometer
(f) = 18.0° C.

d = the difference between the two thermometers =
 14.5° C.

According to the table we find the maximum-saturation of air at the temperature of the wet-bulb thermometer (f) is 15.33 grams of water in 1 cubic meter.

The formula $m = M - cd$ is now as follows :

$$m = 15.33 - (0.65 \times 14.5), \text{ or}$$

$$m = 15.33 - 9.425, \text{ or}$$

$$m = 5.905, \text{ the absolute humidity of the air.}$$

Calculation of the relative humidity.—According to the table we find the maximum-saturation at the temperature of the dry-bulb thermometer, $32.5^{\circ} \text{ C.} = 34.45$ grams, and the absolute humidity at $32.5^{\circ} \text{ C.} = 5.905$ grams. The difference between the two, or deficiency of saturation $= 28.545$ grams. Therefore, at 32.5° C. , the air under observation is capable of taking up 28.545 grams per cubic meter, in addition to the moisture it already holds.

The maximum-saturation is in proportion to the absolute humidity as $34.45 : 5.905 :: 100 : x$.

Therefore $x = 17.14$ per cent. $=$ the relative humidity of the air.

3. Estimation of moisture in the air by chemical methods.—A quantitative estimation of the moisture in the air is made by aspirating a known volume of air through some absorbent material, the weight of which has been carefully determined, and thus any increase in its weight will represent the amount of moisture, in grams, absorbed from the measured volume of air aspirated through it. Pumice stone, saturated with concentrated sulphuric acid, is used for this purpose. It is placed in an absorption flask through which the air is aspirated, the volume of air aspirated being determined by means of a graduated aspirator.

4. The hygroscope.—The hygroscope is employed for the qualitative study of changes in the amount of moisture in the air. The operation of these instruments depends on the expansion and contraction of certain substances, as straw, the bristles of chaff, etc., or on changes in the color of certain salts, as cobalt, nickel, or chromium salts, as the result of changes in the humidity of the atmosphere. These instruments are, however, not adapted for hygienic observations.

5. Evaporation of moisture from the earth's surface.—

a. Evaporimeter.—The evaporation of moisture from the earth's surface can be estimated quantitatively by means of an instrument known as an evaporimeter. It consists of a square tin chamber the surface area of which is 100 sq. cm., and is about 4 cm. in height. It is closed at the top by means of a conical wire cover of wide mesh. The chamber is filled with distilled water to two-thirds its height, its weight accurately determined, and then placed where the observation is to be made. After twenty-four hours it is again weighed when the loss in weight will represent the amount of water evaporated.

The loss in weight, in grams, divided by 100, the surface area of the chamber, gives the amount of evaporation for 1 cm. in height, or multiplying this amount by 10 the result is expressed in millimeters.

Example.—

Grams.

Weight of chamber, Aug. 20, with water	= 650
“ “ “ “ 21, “ “	= 578
“ “ water evaporated in 24 hours	= 72

The air must have free access to the instrument from all sides, but it must be protected from direct sunlight and rain. The amount of moisture evaporated is dependent upon the relative humidity of the atmosphere and upon the relative amount of moisture in the soil. The rate at which evaporation takes place is dependent upon the temperature,—the higher the temperature the greater the rapidity, and the larger the amount of evaporation.

b. Pische's atmometer.—This instrument consists of a graduated glass tube, sealed at one end, which is filled with water and suspended in the air. The lower end of the tube is closed by means of a piece of paper of definite size which has a small perforation to allow the water to evaporate slowly.

The water in the tube of the apparatus passes through the fine opening in the paper as fast as evaporation takes place, and air enters to take its place, thus forming the index of the volume of water evaporated from the paper, the amount varying with the size of the paper. The amount of evaporation is indicated on the graduated scale of the glass tube.

G. PRECIPITATION OF MOISTURE

Moisture is precipitated either in the form of rain, snow, hail, or sleet.

a. Rain.—The amount of precipitation in the form of rain is estimated by means of the rain-gauge. This instrument consists of a cylindrical tin chamber measuring 500 sq. cm., or $1/20$ sq. m. at the top, and has a funnel-shaped bottom which terminates in a short tube

through which the rain-water collected by the chamber is conducted into a vessel placed beneath it. The rain is prevented from splashing over the sides of the chamber by the vertical rim, about 15 mm. in height, which projects from the upper edge of the funnel.

The water collected by the apparatus in an hour, or during the observation period, is measured in the graduated cylinder and the amount calculated for a millimeter in depth, the result obtained indicating the amount of rainfall in millimeters.

Example.—Quantity of water collected in 24 hours = 215 cc., $\frac{215}{500} = 0.43$ mm. of rainfall.

b. Snow, hail, and sleet.—The amount of snowfall is also estimated by means of the rain-gauge. The snow that collects in the vessel beneath the cylinder, during the observation period, is first melted and the water formed from it is then measured and the amount per millimeter calculated as in the case of rain.

The amount of precipitation as hail and sleet may be estimated in the same manner as in the estimation of snowfall.

Position of the rain-gauge.—The rain-gauge should be at least 1.5 m. above ground and placed in such a position as to escape the influence of eddying air-currents, and must, therefore, not be near any object. It may be placed on the middle of the roof of a building, high enough from its surface to escape the influence of eddying currents.

H. WIND: FORCE, RAPIDITY, AND DIRECTION OF CURRENTS OF AIR

As the result of changes in temperature the density of the air is changed and sets in motion large masses of air, that having the greatest density displacing that which is less dense. The direction in which the movement takes place is always along the line of least resistance and toward the point of least density. The rapidity of the movement is directly proportional to the magnitude of the change in density; *i. e.* to the rise in the temperature. These movements of masses of air we call winds, and the most important cause of winds is variations in the amount of heat transmitted from the sun in different latitudes, and at different altitudes on the earth's surface, and the variations in temperature arising from the daily revolutions of the earth on its axis.

a. Qualitative Estimation of Air Movements

1. **In closed rooms** candles, smoke, air-balloons or dynamic manometers may be used to determine the amount and direction of air movement, but a movement of less than 0.2 meter per second cannot be estimated by these means.

2. **Wind vane.**—In the open air the senses and wind vanes are employed. The wind vane indicates the direction in which the air is moving. It consists of a wooden or metallic pointer the exact shape of which is not of vital importance, an arrow, or a representation of some animal, being the most common form in use. It is placed in a horizontal position on the end

of a vertical rod so that it can revolve with the greatest facility. The point of suspension is not quite at the center of gravity, one end being slightly heavier, and this end is also expanded somewhat on its vertical plane so as to afford a point of contact for the wind, while the lighter end is generally more compact in structure so as to offer as little impediment to its movements as possible. The lighter end points in the direction from which the wind is coming. The direction of the air movement, *i. e.*, from which the wind comes, is expressed in points of the compass.

b. Quantitative Estimation of Air Movements

The designations in common use to describe the velocity of the wind denote movements ranging from calm, when no movement is perceptible, to the movement of greatest velocity which is known as "hurricane." The designations denoting velocities between these two extremes, as the velocity increases, are: weak, perceptible, fresh, strong, and storm. The velocity of the air movements is usually expressed so as to indicate the distance traveled in a definite period of time, as meter per second. Instead of expressing the air movement in terms representing the distance traveled in a definite period of time, we also express it in terms of the degree of force which it exerts when coming in contact with an object, as kilograms per square meter. The velocity of the air movements may also be expressed so as to designate the effect produced by it upon different objects, with which it comes in contact, as, when there is a calm smoke rising and the leaves are undisturbed, a slightly

greater movement causes leaves to move, and as the velocity of the current increases the effects are the movement of small branches, of larger branches, whole branches, until we have the effects of a hurricane in the unroofing of houses and the uprooting of large trees. All the different modes of expressing the amount of air movement have been arranged into a scale of thirteen degrees—from 0 to 12—by Beaufort. (See Beaufort's scale.)

BEAUFORT'S SCALE OF DIFFERENT DEGREES OF
AIR MOVEMENT.

Beau- fort's de- grees.	Designa- tion.	Velocity in m. per second.	Pressure in kg. per sq. m.	Effect of the wind.
0	Calm	1.5	0.3	Smoke rises; leaves
1		3.5	1.5	are undisturbed.
2	Weak	6.0	4.4	Perceptible to the
3		8.0	7.8	senses, moves leaves
				and sails.
4	Breeze	10.0	12.2	Moves leaves and the
5		12.5	19.0	smaller branches —
				stretches sails.
6	Fresh	15.0	27.4	Moves the smaller
7		18.0	40.0	branches of trees.
				Moves whole branch-
8	Strong	21.5	56.0	es and weaker stems,
9		25.0	76.0	and hinders one in
				walking.
				Shakes whole trees,
10	Storm	29.0	103.0	breaks branches and
11		33.5	137.0	stems, and uproots
				smaller trees.
				Unroofs houses,
12	Hurricane	40.0	195.0	blows down chim-
				neys, breaks and up-
				roots trees.

Anemometer.—The determination of the rapidity of the air movements is made by means of the anemometer. One form of this instrument consists of two bars crossing at right angles to each other, the distal ends of which bear a small cup-shaped vessel, arranged in such a manner that each in turn presents its concave face toward the wind. These bars are placed on the top of a vertical revolving shaft. The revolutions of the shaft are communicated to a set of pointers revolving over dials. The velocity of the wind, expressed in meters per second, is registered on the dials and may be at once read off by observing the instrument for a minute.

The form of anemometer which is used in estimating air movements in the ventilating shafts of buildings consists of a small wheel bearing a number of flat blades radiating from its axis and placed at such an angle that each, in turn, receives the impulse of the air current and consequently causes the wheel to revolve. The revolutions of the wheel are transmitted to a set of indices, each revolving over the face of the dial, and registering the velocity of the current in meters or feet.

Direction of the wind—wind vane.—The direction of the air movements are denoted by points of the compass. The designations adopted by international agreement are as follows:

N. for north	S. for south
NNE. " north-northeast	SSW. " south-southwest
NE. " northeast	SW. " southwest
ENE. " east-northeast	WSW. " west-southwest

E.	for east	W.	for west
ESE.	“ east-southeast	WNW.	“ west-northwest
SE.	“ southeast	NW.	“ northwest
SSE.	“ south-southeast	NNW.	“ north-northwest

I. FOG AND CLOUDS

a. Fog.—Fog results from the cooling of moist air below the dew-point and consists of fine droplets of water.

b. Clouds.—When the condensed moisture of the air collects as fog in the lower strata and rises into the upper strata it takes the form and appearance which we call clouds. According to the different forms which clouds assume under different atmospheric conditions they have been divided into four principal types: (*a*) cirrus—light and feathery—which rise to a great height, 4000 to 6000 meters or more; (*b*) cumulus—hemispherical or conical heaps like mountains rising from a horizontal base—which rise to a height of 500 to 2000 meters; (*c*) stratus—widely extended continuous horizontal sheets, often forming at sunset; (*d*) nimbus or rain-cloud—is a horizontal sheet of grayish color, and is a mixture of the first two types, and rises to a height of less than 500 meters.

Between the three principal types we have composition forms, as cirro-cumulus, cirro-stratus, and cumulostratus.

Estimation of the amount of cloud.—This is done by a system of numbers: 0, indicates a cloudless sky, and 10, a fully clouded sky, and the intermediate numbers indicate the various intermediate degrees of cloudi-

ness. In making an observation the eye is directed toward a point midway between the horizon and zenith, then slowly turning round the eye is carried along that plane and the relative amount of clear and clouded sky noted.

DESIGNATION OF AMOUNT OF CLOUD FORMATION.

- cloudless = 0
- ◐ half covered = 5
- ◑ three-quarters covered = 7
- entirely covered = 10,

Representations of results of observations.—The results of meteorological observations can be presented in a tabulated form or they can be presented graphically, though the latter method may unduly magnify slight variations, or, on the other hand, it may imperfectly represent the variations that exist.

Weather prognostication.—From the observation of meteorological conditions the following principles have been established which give a definite insight into the changes of the weather:

1. The condition of the weather is influenced directly by the direction of the wind.
2. The direction of the wind is influenced directly by the barometric pressure, which again is directly influenced by
 - a*, the altitude of the location,
 - b*, the specific gravity of the air, according
 - c*, to the humidity of the atmosphere, and
 - d*, the temperature.
3. The air flows from an area with high barometric

pressure towards such areas that have a lower barometric pressure, or from anticyclone toward cyclone, or depression areas.

4. The rapidity of this movement of the atmosphere is directly dependent upon the magnitude of the difference in the barometric pressure in adjacent areas.

5. In consequence of the earth's movements the movement of the atmosphere is not in a vertical direction from the isobars, but in such a manner that the observer (in north latitude), with his back toward the wind, has the anticyclone area before and to the left of him, and the cyclone area back of him and to the right.

6. The weather in the anticyclone area is settled, dry, and clear; in the cyclone area it is variable, cloudy, and rainy.

7. The areas of anticyclone change their form and position more slowly than those of cyclone, while the latter nearly always pass to the right of the former in their movements.

8. Low temperature is indicative of the approach of the anticyclone area and high temperature of cyclone areas.

The meteorological conditions of the country are telegraphed twice daily—8 A.M., and 8 P.M.—to the seat of government where they are tabulated and represented graphically upon a map of the entire country. Localities that have the same barometric pressure are connected by means of lines—isobars—in like manner the localities having the same temperatures; these lines are termed isotherms.

J. IMPURITIES IN THE AIR

The impurities in the air are both gaseous and solid.

a. Gaseous impurities.—The more important gaseous impurities in air that are of interest to the hygienist are: carbon monoxid, carbon dioxid, hydrogen sulphid, marsh-gas, and gaseous organic substances and ammoniacal compounds. The air of manufacturing establishments may contain other gaseous impurities.

b. Solid impurities.—The solid impurities in air are: living organisms, such as bacteria, etc., and various forms of dust. The solid impurities in the air which we recognize as dust particles consist of various forms of *débris* arising from the disintegration of portions of animal and vegetable life, and minute particles of mineral matter.

CHAPTER II. CHEMICAL ANALYSIS OF AIR

The normal and abnormal constituents of atmospheric air which are of hygienic interest and for the presence of which it is necessary to make air analyses are: the relative proportion of oxygen, carbon dioxid, aqueous vapor, and the determination of the presence of hydrogen sulphid, marsh gas, carbon monoxid, and organic matter. Under special conditions, as in the air of manufacturing establishments, air analyses must also be made to determine the presence of poisonous metals and their compounds, as phosphorus, zinc, arsenic, mercury, sulphur dioxid, nitrous, hydrochloro-

ric, and sulphurous acids, chlorin, and of carbon disulphid.

A. OXYGEN

Though the relative proportion of oxygen in the air varies within very narrow limits under ordinary conditions, it is, however, at times desirable to make quantitative estimations of the amount of oxygen in the air of confined spaces.

Process.—A ready method for the estimation of the oxygen in the air is by means of the Bunte gas-burette. This consists of a large graduated burette of over 160 cc. capacity, closed at each end by means of a glass stop-cock, the upper portion being expanded into a bulb. The upper end of the burette is closed by means of a three-way stop-cock through which communication can be made either with the small cup-shaped reservoir at the top and the interior of the burette, or with the outside air. In order to prevent rapid changes in the temperature of the sample of air under analysis the body of the burette, between the upper and lower stop-cocks, is surrounded by a glass tube of larger calibre than the burette, the ends of which are hermetically sealed to the outside of the burette and the intervening space is filled with water, forming a water-jacket for the body of the burette. The capacity of the burette is shown on a scale engraved on the stem of the tube, the zero-point being some distance above the lower stop-cock. From the zero-point the scale extends downward for 10 cc. nearly to the lower end of the tube, and upward for 100 cc., which is just below the expanded portion. From the 100 cc. mark to the upper stop-cock the capacity is 50 cc. The cup-shaped reservoir at the top of the burette serves to hold the solutions of the reagents used in the analysis and is graduated at 20 cc. and at 25 cc.

Before collecting a sample of air for analysis the burette is filled with distilled water, and the reservoir at the top to the 20 cc. mark. The large three-way stop-cock at

the top is now turned so as to establish communication with the interior of the burette and the outside air, when, on opening the lower stop-cock, the water in the burette flows out and the air enters through the stem of the three-way stop-cock. As soon as about 150 cc. of the water have escaped the lower stop-cock is closed, and then the upper stop-cock is turned so as to establish communication between the reservoir and the interior of the burette. With 20 cc. of water in the reservoir the volume of air in the burette will adapt itself to the pressure which it exerts by either allowing some of the water to pass into the burette if it is under less pressure, or by forcing some of the air out of the burette if it is under greater pressure. As soon as the sample of air in the burette has been placed under the pressure of the 20 cc. of water in the reservoir, the three-way stop-cock is turned so as to shut off all communication with the outside and the burette is set aside for several minutes to allow all the water to settle to the bottom of the tube. The volume of the sample of air taken is then read off on the scale.

A portion of the water remaining in the burette is now withdrawn, by cautiously opening the lower stop-cock, thus lessening the density of the air in the burette. A larger portion of water can be removed by connecting the lower end of the burette with a filter-pump. The water in the reservoir is poured out and about 10 cc. of a 25 per cent. solution of potassium hydroxid is poured into the cup; the three-way stop-cock is carefully turned so as to allow the reagent to flow into the burette. To facilitate the action of the reagent the burette is turned upside down several times during five minutes. The potassium hydroxid solution combines with the carbon dioxide in the air and it also renders the water in the burette strongly alkaline. After the air has again been brought under the pressure of 20 cc. of water in the reservoir, and the burette has been set aside for two or three minutes, another reading is made, the decrease in the volume of the sample of air indicating the amount of carbon dioxide contained in it.

The density of the air in the burette is now again decreased by removing some of the liquid through the lower

stop-cock. The water in the reservoir is poured out and 10 cc. of a 25 per cent. solution of pyrogallic acid, in water, is poured into the cup and, turning the three-way stop-cock, it is allowed to pass into the burette. In strongly alkaline solutions this reagent combines with the oxygen very readily. By turning the burette upside down several times during five minutes the reagent is brought in contact with every portion of the air. The pressure within the burette is now again brought to the standard adopted for the other readings—that of 20 cc. of water in the reservoir—and the volume of the sample of air noted. The decrease in the volume as shown by the second and third readings of the burette indicates the amount of oxygen in the sample of air. The results in air analyses are usually expressed in per cent., less frequently in parts per 1000 or 10,000 parts of air. The portion of the sample of air remaining in the burette after the absorption of the carbon dioxid and oxygen may usually be considered as nitrogen.

Example.—

Volume of the sample of air taken for analysis	cc. = 148.7
Second reading	= 148.6
Difference—carbon dioxid	= 0.1
148.7 : 0.1 :: 100 : x = 0.06 per cent. carbon dioxid.	

Second reading	cc. = 148.6
Third “	= 119.2
Difference—oxygen	= 29.5
148.7 : 29.5 :: 100 : x = 19.83 per cent. oxygen.	

First reading	cc. = 148.7
Volume of carbon dioxid and oxygen	= 29.6
Difference — nitrogen	= 119.1
148.7 : 119.1 :: 100 : x = 80.09 per cent. nitrogen.	

B. CARBON DIOXID

1. Qualitative Estimation

From the fact that carbon dioxid is always present

in the air, qualitative determinations have no scientific value.

2. Quantitative Estimation

The most reliable methods for the quantitative estimation of carbon dioxid in air are the two introduced by Prof. von Pettenkofer.

The Pettenkofer flask method.—This method is based upon the reaction of carbon dioxid with a solution of barium, strontium, or calcium hydroxid in water, producing an insoluble carbonate of the base. The reduction in the alkalinity of the hydroxid solution indicates the amount of carbonate that has been formed, and is determined through titration against an acid solution, usually a solution of oxalic acid since this reacts upon the hydroxid solution in a similar manner as the carbon dioxid—the formation of an insoluble salt of the base. The barium hydroxid solution is now generally employed in the estimation of carbon dioxid in air. The solution of oxalic acid employed is made of a definite strength: 1 cc. oxalic acid = 0.25 cc. carbon dioxid.

Oxalic acid solution.—One molecule oxalic acid = one molecule carbon dioxid, hence

1 molecule carbon dioxid = 44 parts by weight.

1 " oxalic acid = 126 parts by weight.

1 mg. carbon dioxid = 0.5084 cc. carbon dioxid (at 0° C. and 760 mm.).

44 mg. carbon dioxid = 22.3696 cc. carbon dioxid.

Therefore 126 mg. $C_2H_4O_4 \cdot 2H_2O$ = 22.3696 cc. carbon dioxid.

Since 1 cc. of the oxalic acid solution = 0.25 cc. of carbon dioxid, the equation:

$22.3696 : 126 :: 0.25 : x = 1.405$ mg. oxalic acid, shows that 1.405 grams oxalic acid must be dissolved in a liter of distilled water. It is necessary to measure the water accurately and therefore the solution must be made up in a graduated flask of a liter capacity. This solution must be protected from light in dark, glass-stoppered bottles.

Barium hydroxid solution.—This solution is prepared of such strength that 25 cc. of it are about equal to 25 cc. of the oxalic acid solution. For this purpose 3.5 grams of pure, alkali-free barium hydroxid are dissolved in 1 liter of distilled water. In case the hydroxid should not be entirely alkali-free it is best to add 0.2 gram barium chlorid to each liter of the solution. In order to protect the barium hydroxid solution from the carbon dioxide of the air, the solution is preserved in a flask having two glass tubes passing through the cork stopper. One of the glass tubes reaches almost to the bottom of the flask and is bent over above the stopper and passes down along the outside of the flask nearly to the bottom when it again bends upward. The mouth of this tube is closed with a short piece of rubber tubing closed by means of a pinch-cock. The second glass tube is cut off just below the inner edge of the cork, and outside of the flask it is twice bent at right angles and extends down to the neck of the flask where it passes through the cork stopper of a small wide-mouthed bottle containing pumice stone saturated with strong potassium or sodium hydroxid solution. The cork stopper of the small wide-mouthed bottle carries another glass tube

which reaches nearly to the bottom of the bottle, while the portion outside the bottle is about 20 cm. in length, and is bent at right angles above the cork. The mouth of this tube is also closed with a short piece of rubber tubing closed with a pinch-cock. This arrangement allows the barium hydroxid solution to be withdrawn from the "store bottle" by inserting the point of a pipette into the end of the rubber tubing attached to the glass tube that reaches nearly to the bottom of the flask, while the air that enters to take its place, passes through the wide-mouthed bottle containing the pumice stone, and then through the second tube in the cork stopper of the store bottle into the flask. In passing through the small wide-mouthed bottle the air is freed of carbon dioxid by the solution of caustic with which the pumice stone is saturated, thus preserving the alkalinity of the barium hydroxid solution.

Indicators.—For the purpose of sharply defining the point of neutralization of the barium hydroxid solution in titrating it with the oxalic acid solution we employ a solution of some substance which undergoes a change in color when its reaction is altered.

a. Rosolic acid solution.—A solution of rosolic acid is commonly employed for this purpose. It gives a delicate rose tint to the alkaline solution of barium hydroxid which gradually fades as the point of neutralization approaches and is completely decolorized by a drop of the acid solution in excess.

The rosolic acid solution is made by dissolving 1 gram in 500 cc. of 80 per cent. alcohol. This solu-

tion is slightly acid in reaction, yellow in color, and is neutralized by the addition of barium hydroxid solution until its color changes to red.

b. Phenolphthalein solution. — Another indicator that is also frequently used is an alcoholic solution (1 to 30) of phenolphthalein. In acid solution this indicator is colorless, but the least trace of alkali changes it to a deep violet color.

Apparatus required.—

a. Four-liter flask. — The samples of air are collected in a flask of about four liters' capacity that has been accurately tared. This is done by thoroughly cleansing it and, when dry, weighing it empty. It is then filled with distilled water at 15° C. so that the water stands level with the mouth of the flask when it is again weighed, the increase in weight, in grams, indicating its capacity in cubic centimeters.

Example. —

	Grams.
Weight of flask with water	= 5250
“ “ “ empty	= 1250
Capacity “	= 4000

or 4000 cc. = 4 liters.

The mouth of the flask is closed with a closely-fitting rubber cap.

b. Hand bellows.—A hand bellows with a long rubber tube attached to its nozzle is used to force the air to be examined into the flask, thus replacing that contained in the flask, for which about 100 strokes of the bellows are necessary.

c. Thermometer.—A mercurial thermometer, registering tenths of a degree centigrade, is required to ob-

serve the temperature of the air at the place where the sample is collected.

d. Barometer.—It is necessary to observe the barometric pressure at the time the sample is collected. The barometer may be at a convenient place in the laboratory and need not be taken to the place where the sample of air is collected.

e. Pipettes.—A 100 cc., and a 25 cc., pipette are required, the former to measure the barium hydroxid solution used to precipitate the carbon dioxid in the air, and the latter to measure the barium solution in making the titrations.

f. Burette.—A Mohr's burette with glass stop-cock, graduated in tenths of a cubic centimeter, is employed to hold the oxalic acid solution.

g. Florence flasks.—Several Florence flasks of 100 cc. capacity are required to hold the barium hydroxid solution for the titrations.

h. Glass-stoppered bottles.—Several small glass-stoppered bottles, of 125 cc. capacity, are needed in which the barium solution is preserved, after it has been exposed to the sample of air, to allow the precipitated barium carbonate to subside.

Collection of the sample of air.—The four-liter flask is carefully dried and taken to the place where the sample of air is to be collected and allowed to remain about fifteen minutes if the temperature differs considerably from that of the laboratory. The thermometer should be placed near the flask at the same time. The rubber tube attached to the nozzle of the bellows

is now placed into the mouth of the flask, extending almost to the bottom. Care must be taken to prevent the entrance of expired air, and, in collecting samples out of doors, it is best to place the bottle to windward, holding the bellows as far as convenient from the body, and with the open side of the bellows turned toward the wind. About 100 strokes of the bellows are sufficient to completely change the air in the flask. The mouth of the flask is then closed with a rubber cap and the temperature of the air, as recorded by the thermometer, is noted.

The flask containing the sample of air is now brought into the laboratory and 100 cc. of the barium hydroxid solution is at once placed in the flask by carefully lifting the edge of the rubber cap sufficiently to permit the introduction of the 100 cc. pipette into the flask as far as the bulb, then carefully replacing the rubber cap. When there is much difference between the temperature of the sample of air and that of the laboratory, it is preferable to introduce the barium solution into the flask before it is removed from the place where the sample has been collected, in order to avoid the loss of a part of the air, or the entrance of laboratory air, while introducing the barium solution, because some alteration takes place in the density of the air in the flask as the result of the higher or lower temperature in the laboratory.

The barometer should now be read and the temperature indicated by the thermometer attached to the barometer must also be noted. The barium solution in the flask should be agitated from time to time by

rolling the flask on the table, or rotating it with the hands, care being taken to avoid the splashing of the solution against the rubber cap. After half an hour the barium solution is transferred to a 125 cc. glass-stoppered bottle and set aside for the precipitate to subside.

Titration of the solutions.—While the barium solution is being agitated with the air in the flask, the alkalinity of this reagent should be determined. By means of a pipette 25 cc. of the barium solution are taken from the "store bottle" and placed in a 100 cc. Florence flask and several drops of the indicator solution added to it. The Mohr's burette having been filled with the oxalic acid solution, the acid solution is slowly added to the barium solution until the indicator, by its changed color, shows that the point of neutralization has been reached. The burette is then read and denotes the number of cubic centimeters of oxalic acid solution that are required to neutralize 25 cc. of the barium solution.

Reading the burette.—It is necessary to deduct 0.1 cc. from the reading of the burette because it required the further addition of 0.1 cc. of oxalic acid solution to change the color of the indicator, after all the barium had been neutralized, the greater affinity of the barium for the acid preventing the reaction on the indicator until all the barium had first been acted upon.

The alkalinity of the barium solution must be determined each day when a sample of air is collected, and the results obtained are then used subsequently

for comparison with those obtained for the alkalinity of the barium solution that has been exposed to the sample of air collected at the same time. Unless the alkalinity of the barium solution is determined for each analysis the results may be unreliable on account of its great liability to undergo change.

After standing for three or four hours the precipitated barium carbonate has subsided leaving a clear supernatant liquid. To determine the reduction in the alkalinity of the barium solution through the action of the carbon dioxide in the air, 25 cc. of the clear supernatant liquid are carefully removed with a pipette and transferred to a Florence flask of 100 cc. capacity and several drops of the indicator added to it. It is then titrated with the oxalic acid solution as before, when the difference between the amount of oxalic acid solution now required and that for the fresh barium solution at the time the sample was collected, will represent the reduction in the alkalinity, in one-fourth of the barium solution employed in the analysis. From this result can be calculated the proportion of carbon dioxide in the air. It is best to make duplicate, or triplicate titrations, and then take the mean of the results obtained.

Example. — At the time the sample of air was collected 25 cc. barium hydroxid = 24.8 cc. oxalic acid solution: now, 25 cc. barium hydroxid = 23.6 cc. oxalic acid solution; therefore in each 25 cc. barium hydroxid solution the equivalent of 1.2 cc. oxalic acid solution have been precipitated by the carbon dioxide in the air, or the total amount of carbon dioxide in the sample is equivalent to $4 \times 1.2 = 4.8$ cc. of oxalic acid solution. Since 1 cc. oxalic acid solution = 0.25 cc. carbon dioxide, we have

$4.8 \times 0.25 = 1.2$ cc. of carbon dioxid in the sample of air.

Calculation of the results.—

a. Correction for barometric pressure.—The barometric reading is reduced to 0° C. according to the

formula: $b_0 = \frac{b'}{1 + a.t}$.

Example.—The barometer at the time the sample of air was collected stood at 764.7 mm., the thermometer attached registering 21.3° C.

$$\text{Therefore } b_0 = \frac{764.7}{1 + 0.00018 \times 21.3} = 761.77 \text{ mm.}$$

b. Reduction of the air volume to normal conditions.—At 0° C., and 760 mm., according to the formula

$$V_0 = \frac{V.b_0}{760 \times (1 + a.t)}.$$

Example.—The capacity of the flask employed,—the air volume,—is 3814 cc., and the temperature of the air at the place where the sample was collected was 14.6° C. The air volume is, therefore, $3814 - 100 \text{ Ba(OH)}_2 = 3714$ cc.

Therefore

$$V_0 = \frac{3714 \times 761.77}{760 \times (1 + 0.00366 \times 14.6)} = 3628.96 \text{ cc.,}$$

the air volume at 0° C., and at 760 mm.

c. Calculation of per cent. of carbon dioxid found.—The amount of carbon dioxid found is 1.2 cc.

Therefore $3628.96 : 1.2 :: 100 : x = 0.03306$ per cent., or 3.306 parts of carbon dioxid in 10,000 parts of air.

Pettenkofer's tube method.—Another method for the estimation of carbon dioxid in the air is that known

as Pettenkofer's tube method. In this method specially devised absorption tubes are employed.

Into each of these absorption tubes is placed 100 cc. of barium solution and a measured quantity of air aspirated through them. The quantity of air flowing from the aspirator represents the volume of air aspirated. A thermometer is placed adjacent to the tubes to register the temperature of the air. This thermometer should be read at the beginning and at the end of the aspiration of air, and the mean of the two observations taken as the temperature of the air volume aspirated. The barometer must also be read during the time that aspiration is going on.

C. AQUEOUS VAPOR

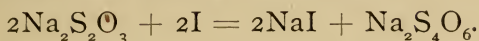
The method for the quantitative estimation of moisture in air has already been considered.

D. HYDROGEN SULPHID

Hydrogen sulphid is detected by its characteristic odor and by its action (blackening) on paper moistened with solution of lead acetate, forming black sulphid of lead.

For its quantitative estimation a known volume of air is aspirated through a titrated solution of iodine, the hydrogen sulphid being reduced as follows: $\text{H}_2\text{S} + 2\text{I} = 2\text{HI} + \text{S}$. The uncombined iodine remaining in solution is then estimated through titration with a standard ($n/10$) solution of sodium thiosulphate, using starch paper as an indicator, the iodine

coloring the starch paper a deep blue color. The reaction which takes place is as follows :



1. *Iodin solution*.—A 1/10 normal iodine solution, containing 12.685 grams of pure iodine, dissolved in 1 liter of distilled water with the aid of 18 grams of pure potassium iodide. 1 cc. of this solution = 1.7 milligrams hydrogen sulphid.

2. *Sodium thiosulphate solution*.—A 1/10 normal solution of sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$) is made by dissolving 24.808 grams of pure, crystalline sodium thiosulphate in 1 liter of distilled water. 1 cc. of this solution = 1.7 milligrams hydrogen sulphid.

Both of these solutions must be protected from the air in glass-stoppered bottles.

3. *Starch paste*.—Freshly boiled starch paste is made by boiling 1 gram of potato starch in 100 cc. of water.

Process.—The air is aspirated through 100 cc. of the normal iodine solution contained in an absorption flask, or a Pettenkofer absorption tube. After several hundred liters of air have been slowly aspirated through the iodine solution it is transferred to a small glass-stoppered bottle, then 25 cc. of it are placed in a 100 cc. Florence flask with 1 cc. of the starch paste. The normal sodium thiosulphate solution is then added from a burette until the iodine solution becomes colorless. The difference between the amount of sodium thiosulphate solution required to decolorize 25 cc. of the iodine solution, before and after its exposure to the air, indicates the amount of hydrogen sulphid in the air. The results are expressed so as to show the number of milligrams of hydrogen sulphid in 1 cubic meter of air.

E. CARBON MONOXID

a. **Qualitative tests.**—The spectroscope is usually employed to determine the presence of carbon monoxid in air. For this purpose 10 cc. of fresh blood are diluted with 40 cc. of distilled water and poured into a flask of 6 to 10 liters' capacity. The flask is then filled with the air under examination by means of a hand bellows and closed with a rubber cap. The diluted blood is agitated with the air for fifteen to twenty minutes so as to bring it in contact with all the carbon monoxid in the air. The carbon monoxid displaces the oxygen in the oxy-haemoglobin of the blood and forms CO-haemoglobin.

Ten drops of this blood, as well as a like quantity of normal blood, are each diluted to about 20 cc. and compared by means of the spectroscope. Oxy-haemoglobin, or normal blood, shows in the yellow and green lines of the normal spectrum (Fraunhof's lines D and E [b]) two absorption bands with well-defined margins. CO-haemoglobin also shows these bands, but closer together, and with indistinct margins.

For absolute differentiation the action of some reducing agent on both specimens of blood is to be noted; for instance, the influence of ammonium sulphid. The oxy-haemoglobin is reduced while the CO-haemoglobin remains unchanged. This differentiation is readily made with the spectroscope. One or two drops of ammonium sulphid are added to the diluted blood; this is then gently agitated and again examined spectroscopically. The reduced oxy-haemoglobin now shows an indistinct band lying about midway between

the two haemoglobin bands, while the CO-haemoglobin shows very little change.

b. Chemical tests.—In order to detect carbon monoxid in the air by chemical means, the CO-haemoglobin that is formed when the diluted blood is agitated with the air, is coagulated by heat, and the carbon monoxid that is given off is conducted into a 1 to 500 solution of palladium chlorid. The diluted blood is passed into a flask closed with a doubly perforated cork through which fresh air is aspirated. The air is first conducted through an absorption flask containing palladium chlorid in order to free it of carbon monoxid or any other bodies capable of reducing palladium chlorid. It is then conducted through the flask containing the CO-haemoglobin which has been placed on a boiling water-bath. The air takes up the carbon monoxid, as it is liberated from the haemoglobin, and then passes through the absorption flask containing sulphuric acid where it is freed from moisture. It is then conducted through another absorption flask containing a solution of lead acetate where the ammonia and hydrogen sulphid are taken up, as these would vitiate the reaction. Finally the air passes into the absorption flask containing the palladium chlorid solution where the carbon monoxid is absorbed. The warming of the blood on the water-bath, and the aspiration of air must be continued for at least half an hour. The carbon monoxid precipitates the palladium chlorid as black metallic palladium.

While the spectroscopic method shows the presence

of 2.5 per cent. of carbon monoxid in the air the chemical method shows 0.2 per cent.

F. ORGANIC MATTER

a. Nitrogenous organic matter (Remsen's method—Free and albuminoid ammonia).—The method for the determination of organic matter in the air that is open to least objection is that devised by Prof. Remsen. It consists in aspirating a measured volume of air through a small glass absorption tube containing freshly-ignited, granular pumice stone which has been moistened with pure distilled water. After several hundred liters of air have been aspirated through the tube the pumice stone is transferred to a clean, glass-stoppered retort, 500 cc. of water that is practically free from ammonia is added, and then the free and albuminoid ammonia is determined by the Wanklyn and Chapman method.

b. Oxidizable organic matter.—The organic matter in air may also be estimated as oxidizable matter by boiling the pumice stone, used in the Remsen absorption tube, with a weak, acid solution of potassium permanganate and titrating with solution of oxalic acid as for oxidizable matter in water.

G. ESTIMATION OF DUST IN AIR

1. By weight.—The amount of organic matter in air in the form of dust particles may be estimated by aspirating a measured volume of air through an absorption tube containing freshly-ignited asbestos. The increase in weight of the absorption tube will repre-

sent the weight of the dust particles collected from the known volume of air aspirated. The relative proportion of organic and inorganic matter in the dust may be determined by carefully transferring the asbestos to a weighed platinum crucible and incinerating the organic matter contained in the dust. The loss in weight will represent the organic matter in the dust while the difference between the first and second weighing will represent the inorganic matter.

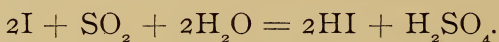
2. The number of dust particles (Aitken's dust counter).—The number of dust particles in a definite volume of air may be estimated by means of Aitken's dust counter. This instrument consists of a small metallic chamber with glass top and bottom. A small lens is placed over the glass top of the chamber while the glass forming the bottom of the chamber is divided into squares of $1/10$ millimeter each. The inner walls of the chamber are lined with bibulous paper which is moistened before making an analysis. To the side of the chamber is attached a small vacuum pump by means of which the air in the chamber can be rarefied, when, on turning a small, three-way stop-cock at the top of the pump, the outside air rushes into the chamber. The stop-cock is then turned so as to close the chamber and connect it with the pump. When the piston of the pump is now rapidly lowered and raised at short intervals, the tension of the air in the chamber is alternately increased and diminished, thus causing the moisture in the paper to vaporize and condense on the dust particles in the air. On looking through the small lens at the top of the chamber the

dust particles are seen to fall within the chamber as minute droplets of water and rest on the ruled glass at the bottom. The total number of droplets falling on one of the squares, after the air in the chamber has been rarefied eight or nine times, with the proportion of impure and pure air in the chamber, afford the data from which the number of dust particles in the air may be estimated.

H. SULPHUROUS ACID

a. **Qualitative test.**—The presence of sulphurous acid in air may be detected by its peculiar penetrating odor.

b. **Quantitative estimation.**—For the quantitative estimation of this gas the air is aspirated through 1/10 normal iodine solution whereby it is oxidized to sulphuric acid:



The 1/10 normal iodine solution is titrated with 1/10 normal sodium thiosulphate solution as in the estimation of hydrogen sulphid. 1 cc. 1/10 normal sodium thiosulphate solution = 3.2 milligrams of sulphurous acid.

I. HYDROCHLORIC ACID

a. **Qualitative test.**—The fumes or vapor of hydrochloric acid in air are detected by their reaction upon silver nitrate in solution, producing a white precipitate of silver chlorid.

b. **Quantitative estimation.**—In the quantitative estimation of hydrochloric acid the air is drawn through

a 1/10 normal solution of sodium hydroxid which is then titrated with 1/10 normal sulphuric acid. The decrease in the alkalinity of the soda solution represents the quantity of hydrochloric acid in the known volume of air aspirated.

J. CHLORIN

In the quantitative estimation of chlorin, known volumes of air are conducted through a solution of potassium iodid (1 gram in 20 cc. of water) whereby the iodine is liberated: $KI + Cl = I + KCl$. The amount of iodine that has been liberated is then determined by titration with 1/10 normal solution of sodium thiosulphate: 1 cc. = 3.55 milligrams chlorin.

K. AMMONIA

a. **Qualitative test.**—Ammonia, when present in the air, in considerable quantities, can be detected by its characteristic odor. When present in smaller quantities it may be detected by means of a strip of litmus, haematoxylon, or curcuma paper placed between two glass plates, in such a manner that one-half of it projects from the margin of the plates and is the only portion acted upon by the ammonia in the air. The presence of ammonia is shown by the changed color of the portion of the paper exposed to the air, the extent to which the color is changed indicating the relative amount of ammonia present.

b. Quantitative estimation.—

1. *Gravimetric method.*—For the quantitative estimation of ammonia large volumes of air are aspirated

through dilute hydrochloric acid with which it unites to form ammonium chlorid. This salt is then precipitated with platinic chlorid and the resulting double chlorid of ammonium and platinum is collected on a filter, dried, and weighed.

2. *Volumetric method*.—By this method large quantities of air are aspirated through pure water acidulated with sulphuric acid which retains all the ammonia. The quantity of ammonia retained is then determined by means of Nessler's reagent.

PART II

WATER

CHAPTER I. THE NATURE AND COMPOSITION OF WATER

a. Physical properties.—Pure water is a colorless, tasteless, and odorless liquid of neutral reaction. At 760 mm. barometric pressure, and at the temperature of its greatest density (4° C.), its specific gravity is taken as 1000, one liter weighing one kilogram. At 0° C. it changes into ice, and at 100° C. it is converted into steam. Its density decreases as the temperature rises above 4° C., and also as the temperature falls below that point. At 0° C., in the form of ice, it has a specific gravity of 0.91674.

b. Chemical composition.—Pure water (H_2O) consists of 2 parts by weight of hydrogen and 16 parts by weight of oxygen, having a molecular weight of 18. Two volumes of hydrogen are combined with one volume of oxygen and form two volumes of water-gas, having a density of $\frac{18}{2} = 9$. The percentage compo-

	Per cent.
Hydrogen,	11.11
Oxygen,	88.89
	<hr/>
	100.00

Water, as it is found in nature, is not chemically

pure, but contains various substances in solution and suspension which it derives from the air and soil. Many of these substances are present in variable quantities in nearly all waters and are therefore not looked upon as impurities, from a hygienic point of view. The substances which fall under this class are: the gases of the atmosphere—oxygen, nitrogen, and carbon dioxid—which all waters hold in solution; the salts of different metals and the alkaline earths, vary in their nature with the character and composition of the soil of the locality—principally chlorid, sulphate, nitrate, carbonate, and silicate of sodium, potassium, calcium, and magnesium.

On the other hand, those substances in water which are called impurities from their detrimental influence on health, do not originate from the natural constituents of the soil but arise from the refuse matter around human habitations, lying within, or on the surface of the soil traversed by the water. The most important of the impurities in water is organic matter, in the form of living and dead vegetable and animal organisms, and their products. As the result of the chemical and vital processes of nature's laboratory, the organic matter in water is constantly being destroyed, the resulting products being ammonia, nitrous and nitric acids, chlorids, carbonates, etc.

CHAPTER II. SANITARY ANALYSIS OF WATER

1. Collection of the Sample

A bottle of about four liters' capacity is cleansed with hot water, then repeatedly rinsed with distilled

water, and, finally, it is rinsed several times with the water to be examined. It is then filled with the water and closed with a clean, new cork that has also first been rinsed in the water. The cork should be held in place with a heavy cord.

In collecting a sample from a pond, lake, or stream the bottle should be immersed for 20 or 30 cm. below the surface of the water in order to avoid the entrance of refuse matter that may be floating on the surface. The sample should be collected at a sufficient distance from the shore to avoid impurities lodged along the banks of the stream or pond. A sample of well water or hydrant water should be collected only after it has been flowing for several minutes. In collecting a sample from a town supply, the end of the supply-pipe should be avoided in order to secure a sample that is fairly representative of the condition of the water.

2. Data on the Label

After the sample of water has been procured, a label should be attached to the bottle giving the following data: (*a*) the source of the sample, and date of collection; (*b*) the presence of any contaminating influences, as the general character of the drainage—the presence or absence of sewers, density of the population, the presence or absence of epidemic diseases.

3. The Physical Examination of the Water

a. **Clearness.**—Note whether the water is clear, opalescent, or cloudy; whether it contains any suspended particles, and their nature.

b. Color.—This is determined by comparison with distilled water by filling a glass cylinder, 50 cm. in height, with the water, and holding it over a white surface. The color may also be estimated by placing 50 cc. of water in a long Nessler tube and comparing it with the standards used in determining the free and albuminoid ammonia. The result is expressed as 0.1 or 0.2 according to the particular standard to which the color corresponds.

c. Odor.—A marked odor can be detected at once on opening the bottle containing the sample of water. When there is only a slight odor a liter flask may be half filled with the water and strongly agitated for several minutes when the odor may be detected on removing the stopper. If this procedure fails a portion of the water should be warmed to 40° C. when, if any odoriferous substances are present, their presence will be manifested by a faint or distinct odor according to their nature. The addition of some potassium hydroxid, before warming, at times hastens the liberation of the odors.

d. Taste.—Aside from organic matter the taste of water is influenced by its temperature and by the quantity of carbon dioxid which it contains.

e. Reaction.—Most waters are of neutral reaction or very slightly acid, an alkaline reaction being comparatively rare. The reaction may be determined with litmus paper, but for accuracy and delicacy the phenolphthalein test is preferable.

Process.—Take 100 cc. of the water and add 1 cc. of the phenolphthalein solution; then add from a burette a dilute ($n/10$) solution of either sodium or potassium hydroxid. The violet tint of the water, showing the neutralization of the acid, is readily noticeable.

4. Chemical Analysis for Impurities

The chemical analysis of water for hygienic purposes consists, ordinarily, in the quantitative estimation of the total solids, of chlorin, free and albuminoid ammonia, nitrates and nitrites, oxidizable organic matter, and the hardness of the water.

The chemical analysis of water may be either qualitative or quantitative in character.

I. QUALITATIVE CHEMICAL ANALYSIS OF WATER

a. Gases

1. **Free carbonic acid** (Pettenkofer's Method).—To 100 cc. of the water add 10 drops of rosolic acid solution. Note the color, as compared with sample of distilled water. Free carbon dioxid turns color to yellow.

2. **Hydrogen sulphid.**—Warm 100 cc. of water in a flask in the neck of which is a strip of filter-paper moistened with solution of lead acetate, and held in place by a loosely fitting cork. Black color indicates hydrogen sulphid.

b. Salts in Solution

1. **Silicic acid.**—250 cc. of water are evaporated to dryness. The residue is dissolved in a few drops of hydrochloric acid, again evaporated to dryness, and

again dissolved in dilute hydrochloric acid. The silicic acid remains undissolved in the form of white flakes, and can be washed, dried, and weighed.

2. Sulphurous acid.—To 50 cc. of water add a few drops of hydrochloric acid and 1 cc. barium chlorid solution. Sulphurous acid is precipitated as heavy white barium sulphate.

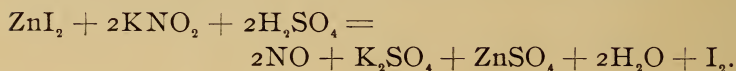


3. Chlorin.—To 50 cc. of water add 5 drops of dilute nitric acid and a few drops of silver nitrate solution. An insoluble, white, flaky precipitate of silver chlorid is formed, dissolving in excess of ammonia.



4. Nitric acid.—Dissolve a few crystals of diphenylamin in 2 cc. sulphuric acid. Float 10 drops of the water on the acid. A blue color indicates the presence of nitric acid.

5. Nitrous acid.—Place 50 cc. of water in a tall glass cylinder, add 5 drops concentrated sulphuric acid, and 1 cc. of zinc-iodin-starch solution. Shake. A blue color indicates the presence of nitrous acid.



6. Phosphoric acid.—Evaporate 250 cc. of water down to 50 cc. in a platinum crucible. Acidify with nitric acid. Add ammonium molybdate solution. A yellow precipitate forms within twenty-four hours.

c. Bases

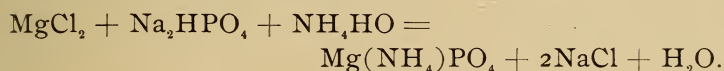
1. **Potassium and sodium.**—(See page 101).

2. **Calcium.**—Acidify 100 cc. water with hydrochloric acid, boil, render alkaline with ammonia, and add 1 cc. ammonium oxalate solution. A white precipitate rapidly forms = calcium oxalate.

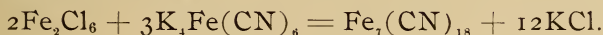


It is necessary to first remove iron and the earthy bases.

3. **Magnesium.**—The precipitate of the oxalate of lime is filtered off, the filtrate again treated with 10 drops ammonium oxalate solution to remove all the lime. Then add ten drops sodium phosphate solution. Stir. White crystalline precipitate of magnesium ammonium phosphate forms.



4. **Iron.**—The residue of 250 cc. of water is dissolved in hot dilute nitric acid, and 5 drops of potassium ferrocyanid solution added. A green to blue color is produced.

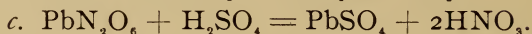
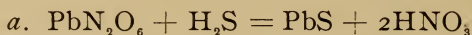


5. **Heavy metals.**—Five liters of water are treated with a few drops of nitric acid, and ammonium nitrate solution. This is evaporated to 50 cc., then treated with hydrogen sulphid.

A black precipitate may be lead or copper.

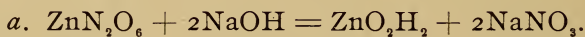
Filter and wash with hydrogen sulphid solution. Dissolve in hot dilute nitric acid, filter, and add a few

drops of sulphuric acid. If lead is present there is a white precipitate of lead sulphate.



Copper.—The filtrate is then treated with potassium ferrocyanid solution. Reddish brown, flaky precipitate is copper in form of ferrocyanid.

Zinc.—The filtrate of the copper serves to show the presence of zinc. Boil to drive off hydrogen sulphid. Add excess of sodium hydroxid. Zinc hydroxid is formed. Filter and treat with hydrogen sulphid gas. White precipitate is zinc sulphid.



6. Ammonia.—Nessler's reagent, 1 cc., added to 50 cc. of the water.



A yellowish color indicates the presence of ammonia.

II. QUANTITATIVE CHEMICAL ANALYSIS OF WATER

1. Total Solids

A definite quantity of the water (100 to 1000 cc.) is placed in a weighed porcelain capsule and evaporated to dryness on a water-bath. The capsule is then dried for an hour, at 100° C., allowed to cool in a desiccator, and again weighed. For very accurate re-

sults the residue must be dried to a constant weight. The increase in the weight of the capsule represents the weight of the solids in the amount of water evaporated.

Incineration of the residue.—In order to determine the proportion of organic and inorganic matter in the solids obtained from the water evaporation, the residue is carefully incinerated, and, after cooling in a desiccator, the capsule is again weighed. The loss in weight represents approximately the organic matter and the remainder the inorganic matter. From the color of the residue, and the odors given off during incineration, we derive some information as to the nature of the organic matter—whether of vegetable or of animal origin; an odor resembling burning hair indicates animal matter. A dark and greasy residue usually indicates the presence of sewage.

2. Chlorin

From the fact that chlorin is found in practically all waters, in variable quantities, quantitative estimations are always necessary. Chlorin in water is estimated by means of a solution of silver nitrate, using a few drops of a solution of potassium chromate as an indicator.

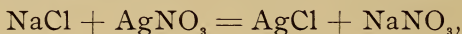
a. Solution of silver nitrate.—The solution of silver nitrate used in the estimation of chlorin in water is made of such strength that 1 cc. = 1 milligram chlorin.

The molecular weight of silver nitrate	=	170,
“ “ “ “ chlorin	=	35.5,

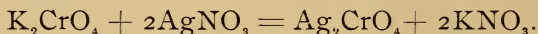
Therefore $35.5 : 170 :: 1 : x = 4.788$ milligrams silver nitrate are equal to 1 milligram of chlorin, and 4.788 grams silver nitrate must be dissolved in a liter of water in order that 1 cc. of solution = 1 milligram chlorin.

b. Solution of sodium chlorid.—The solution of silver nitrate is standardized by titrating against a solution of sodium chlorid of such strength that each cubic centimeter represents 1 milligram chlorin.

$35.5 : 58.5 :: 1 : x = 1.647$ mg. NaCl. = 1 mg. Cl. Therefore 1.647 grams sodium chlorid must be dissolved in a liter of water. The reaction which takes place between these two solutions is as follows:



and, as soon as all the chlorin in the solution has been precipitated by the silver the further addition of a slight excess of the silver solution produces a reaction between it and the indicator, potassium chromate, and is manifested by a change in the color of the solution from the precipitate of red chromate of silver which is now produced, the reaction being



c. The indicator.—This consists of a 10 per cent. solution of potassium chromate which has been freed from chlorin, three or four drops being used for each titration.

Process.—Before each determination of chlorin in water the solution of silver nitrate must be standardized by titrating it against a standard solution of sodium chlorid. Then 100 cc. of the water are placed in a half-liter Florence flask with three or four drops of the indicator, and the silver solution added from a burette, con-

stantly agitating the water in the flask, until the reddish tint produced by the silver chromate remains permanent. In order to avoid adding an excess of the silver solution the flask should be placed in a porcelain capsule, comparing the color of the solution from time to time with that of a duplicate sample in another flask placed under similar conditions, and in which the end-reaction was accurately determined. The number of cubic centimeters of silver solution required to precipitate the chlorin in the water will represent the number of milligrams of chlorin in 100 cc. of the water. From the fact that the end-reaction requires the addition of an excess of silver solution it is necessary to deduct 0.1 cc. from the reading of the burette.

Example. — 100 cc. of water required 1.3 cc. silver nitrate solution; therefore, deducting 0.1 cc. for the end-reaction, we have 1.2 cc. silver nitrate = 1.2 milligrams chlorin in 100 cc. of water. If, however, the silver nitrate solution varies from the normal strength, as shown by its titration against the sodium chlorid solution, it is necessary to make a corresponding correction of the results obtained. For example:

$$10 \text{ cc. NaCl} = 10.1 \text{ cc. AgNO}_3.$$

$$\text{Hence } 10.1 : 10.0 :: 1.2 : x = 1.188 \text{ mg. Cl.};$$

$$\text{or if } 10 \text{ cc. NaCl} = 9.8 \text{ cc. AgNO}_3,$$

$$\text{then } 9.8 : 10 :: 1.2 : x = 1.224 \text{ mg. Cl.}$$

In waters containing much organic matter the color of the water may interfere with the satisfactory detection of the end-reaction when potassium chromate is used as an indicator. In such instances Salkowski's modification of Volhard's method of using ammonium thiocyanate as an indicator should be employed.

Solutions required:

1. Pure nitric acid, of 1.20 specific gravity.
2. Concentrated solution of ammonioferric alum.

3. A standard sodium chlorid solution, 1 cc. = 1 milligram chlorin.

4. A standard silver nitrate solution, 1 cc. = 1 milligram chlorin.

5. A titrated solution of ammonium thiocyanate. This is made by dissolving 2 grams of pure ammonium thiocyanate in water and diluting it to 1100 cc. A burette is filled with this solution, and 10 cc. of the silver nitrate solution are placed in a flask, diluted to 100 cc., and 5 cc. of nitric acid and 5 cc. of the alum solution are added. The mixture is agitated and the thiocyanate solution added in small portions until the red color remains permanent, but still weak. This titration is repeated and then a liter of the thiocyanate solution is diluted until 10 cc. of it are equivalent to 10 cc. of the silver nitrate solution.

Process.—1000 cc. of the water are acidulated with nitric acid, and a known amount of the standard silver nitrate solution is added, enough to leave a small excess. This is well shaken and then filtered through a dry filter. To a measured portion of the clear filtrate (100 cc.) a little alum solution is added, and finally the standard ammonium thiocyanate solution is dropped from a burette until the red color of ferric thiocyanate makes its appearance. The quantity of ammonium thiocyanate solution used (calculated for the entire quantity of water taken) gives the amount of excess of silver solution in the liquid, and this by subtraction from the whole amount of silver solution used, gives the amount corresponding to the chlorin present in the water.

3. Free and Albuminoid Ammonia

The nitrogenous organic impurities in water are generally estimated by the Wanklyn and Chapman process as free and albuminoid ammonia.

a. Nessler's reagent.—Nessler's reagent is prepared by dissolving 62.5 grams of potassium iodid in 250 cc. of water, and to this a hot saturated solution of mercuric chlorid is added until a slight permanent precipitate of red mercuric iodid is formed. Solid caustic potash, 150 grams, dissolved in 150 cc. of water, is then added to the mixture and the solution rendered sensitive to ammonia by the addition of a small amount of the saturated mercuric chlorid solution. It is then filtered through asbestos and preserved in a glass-stoppered bottle.

b. Alkaline potassium permanganate solution.—This solution is prepared by dissolving 8 grams of potassium permanganate in 600 cc. of distilled water, and 200 grams of caustic potash in 500 cc. of water. As soon as each of these has become entirely dissolved the two solutions are mixed and the mixture evaporated to a liter, thereby freeing it of ammonia.

c. Standard ammonium chlorid solution.—A strong solution of ammonium chlorid is prepared by dissolving 3.141 grams of ammonium chlorid in a liter of distilled water. The standard solution is prepared from this strong solution by diluting it 1 : 100 with distilled water when each cubic centimeter will contain 0.01 milligram of ammonia, or 0.0082 milligram of nitrogen.

d. Ammonia-free water.—In making up the standards containing definite amounts of the ammonium chlorid solution, it is necessary to employ distilled water that is practically free from ammonia. This

water must be specially prepared as it is not on the market. The best way to secure such a water is by redistillation of pure distilled water or spring water. At times it has been found almost impossible to obtain a satisfactory water from the city water supply because of the large amounts of sewage contained in it. In preparing ammonia-free water from pure distilled water the first portion of the distillate is always discarded, usually about a third of the distillate. The water distilling over, after the first third has been discarded, is tested with Nessler's reagent, and if found ammonia-free, is collected in a clean glass-stoppered flask. Where this method fails to yield satisfactory amounts it may be advisable to add a few drops of pure, concentrated sulphuric acid to the water before distilling, so as to convert the ammonia into the sulphate, when the distillate will come over fairly free from ammonia.

Process.—A glass-stoppered retort of 1250 cc. capacity, and a Liebig's condenser, with constant water-supply, are required to carry out this process. The retort is thoroughly cleansed and partly filled with pure distilled water. The water is then distilled over until it comes off free from ammonia, as shown by testing 50 cc. of the distillate with 1 cc. of the Nessler reagent. As soon as the distillate is found to be free of ammonia the distillation is stopped, the retort disconnected from the condenser, and the remainder of the distilled water poured out leaving the last drops to drain away. Then, without rinsing, it is again connected with the condenser and 500 cc. of the water to be examined placed in it. The distillation of the water is now begun and each 50 cc. of the distillate collected separately in short glass cylinders and transferred to long Nessler tubes of 50 cc. capacity, which

have been thoroughly cleansed by rinsing repeatedly with pure water, and allowed to drain in a suitable rack or frame. When four portions of 50 cc. each, or 200 cc. altogether, have been distilled over the free ammonia has usually all been removed, and the distillation is arrested. 50 cc. of the alkaline potassium permanganate solution are now added to the remainder of the water in the retort and the distillation resumed. Five portions of 50 cc. each of the distillate are collected as before, these representing the so-called albuminoid ammonia.

A set of standards is now prepared by placing 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, and 1.0 cc. of the standard ammonium chlorid solution into Nessler tubes of 50 cc. capacity and diluting with water that is practically free of ammonia. These are then placed in a suitable rack in regular order according to the strength of the standards they represent. The standards and distillates are now "nesslerized" by adding 1 cc. of Nessler's reagent to the contents of each tube. After standing for ten minutes the comparisons may be made. The total amount of ammonia found in the first four distillates represents the amount of free ammonia in 500 cc. of the water. The total quantity of ammonia found in the last five distillates represents the amount of albuminoid ammonia in the same amount of the water. By multiplying each of these amounts by two we learn the number of milligrams of free and of albuminoid ammonia in a liter of the water.

Example. — The first 50 cc. of distillate = 0.3 cc. of the standard ammonium chlorid solution, or 0.003 mg. of ammonia; the second 50 cc. = 0.15 cc. of the standard solution, or 0.0015 mg. of ammonia; the third 50 cc. = 0.005 cc., or 0.0005 mg. of ammonia; and the fourth 50 cc. = 0.000 cc. of the standard solution. The total amount of free ammonia found in the 500 cc. of water is 0.005 mg., or 0.01 mg. of ammonia in a liter of the water.

The distillates containing the albuminoid ammonia are as follows:

- First = 0.4 cc., or 0.004 mg. of ammonia ;
Second = 0.3 cc., or 0.003 mg. of ammonia ;
Third = 0.2 cc., or 0.002 mg. of ammonia ;
Fourth = 0.1 cc., or 0.001 mg. of ammonia ;
Fifth = 0.05 cc., or 0.0005 mg. of ammonia.

The total quantity of albuminoid ammonia found in the 500 cc. of water is 0.0105 mg., or 0.021 mg. of ammonia in a liter of the water.

4. Oxidizable Organic Matter

a. Oxalic acid solution.—This solution is made of such strength that each cubic centimeter of it will represent 0.1 milligram of oxygen.

Therefore $16 : 126 :: 0.1 : x = 0.7875$ milligram oxalic acid in each cubic centimeter, or 0.7875 gram of oxalic acid are dissolved in a liter of distilled water, so that 1 cc. of the solution = 1 milligram of oxygen.

b. Potassium permanganate solution.—This is likewise made of such strength that 1 cc. of it will equal about 0.1 milligram of oxygen, and therefore, 0.4 gram of potassium permanganate are dissolved in a liter of water.

c. Sulphuric acid of 25 per cent. strength.—

Cleansing the casserole.—A porcelain casserole of about 200 cc. capacity is freed from organic matter by introducing 100 cc. of distilled water, 5 cc. of the 25 per cent. sulphuric acid, and several cubic centimeters of the potassium permanganate solution and boiling for five minutes. This water is then poured out leaving the last few drops to drain away.

Into the clean casserole is now introduced 100 cc. of the water to be examined, 5 cc. of the 25 per cent. sul-

phuric acid, and 6 to 8 cc. of the potassium permanganate solution and boiled for five minutes. Into the hot liquid is now introduced 10 cc. of the oxalic acid solution by means of a pipette, and then the potassium permanganate solution is carefully added, drop by drop, from a Gay-Lussac burette, until the liquid assumes a faint rose tint. The total quantity of the potassium permanganate solution added represents the amount necessary to oxidize the 10 cc. of oxalic acid solution and the organic matter in the 100 cc. of water.

Standardizing the solutions.—In order to ascertain the amount of potassium permanganate solution required to oxidize the 10 cc. of oxalic acid solution, it is necessary to again introduce 6 or 8 cc. of the potassium permanganate solution into the liquid in the casserole, which is now free of organic matter, and heat it to boiling, again adding 10 cc. of the oxalic acid solution, and finally the potassium permanganate solution, drop by drop, until the faint rose tint is reproduced. The amount of potassium permanganate solution required now for the 10 cc. of oxalic acid solution alone will indicate the amount of potassium permanganate solution required to yield 1 milligram of oxygen.

Example.—The 100 cc. of water examined and the 10 cc. of oxalic acid solution required 13.4 cc. of the potassium permanganate solution to bring about the rose tint of the liquid in the first instance. In the second instance the 10 cc. of oxalic acid solution alone required only 10.4 cc. of the potassium permanganate solution to bring about the same result. It is necessary to deduct 0.1 cc. from each of these results as that amount of potassium per-

manganate solution is necessary to bring about the end-reaction. Therefore 10.3 cc. of the potassium permanganate solution represent 1 milligram of oxygen, and the organic matter in the 100 cc. of water under examination required 3.0 cc. of the potassium permanganate solution for its oxidation. From these data we can calculate the amount of oxygen required to oxidize the organic matter in a liter of the water under examination.

$$10.3 : 1 :: 30 : x = 2.912 \text{ milligrams O.}$$

The rôle of the sulphuric acid.—The necessity for the addition of the sulphuric acid in this process is twofold. The reaction of the potassium permanganate is more energetic in acid solutions, and in the second place, the potassium permanganate in breaking up will unite with the sulphuric acid to form manganous sulphate, a colorless salt: $2\text{KMnO}_4 + 3\text{H}_2\text{SO}_4 = 2\text{MnSO}_4 + \text{K}_2\text{SO}_4 + 3\text{H}_2\text{O} + 5\text{O}$.

Boiling for five minutes.—In carrying out this process it is highly important to boil the water for a definite period of time. Some authors recommend boiling for ten minutes and there may be instances where it would be necessary to do so in order to oxidize certain organic substances present in the water, but for most substances boiling for five minutes is considered sufficient. In making comparative estimations it is essential to boil for the same length of time in each determination—always counting from the beginning of ebullition.

5. The Hardness of Water

The hardness of water is due to the presence of lime and magnesia in the form of carbonates, chlorids, sul-

phates, or nitrates. In exceptional instances the hardness of water is also in part due to the presence of salts of iron.

The hardness of water is usually determined by means of a standard soap solution. The fatty acids in the soap solution form insoluble stearates, palmitates, etc., of lime and magnesia. As long as any of the lime and magnesia is unprecipitated the soap solution fails to produce a permanent lather with the water. As soon as a distinct lather is formed, and remains permanent for five minutes, all the lime and magnesia present in the water have been precipitated, and the lather, therefore, forms the indicator of the end-reaction.

a. Standard soap solution.—The standard soap solution is made by softening 150 grams of lead plaster (U. S. P.) on a water-bath and thoroughly mixing it with 40 grams of pure potassium carbonate until a homogeneous mixture is obtained. This mixture is then diluted with dilute alcohol and transferred to a glass-stoppered bottle and agitated at intervals for several days. The solution is then filtered and standardized by means of a solution of barium nitrate—0.559 gram dissolved in a liter of distilled water—of which 100 cc. contain an amount of barium equivalent to 12 milligrams of lime. The standard soap solution is made of such strength that 45 cc. of it are required to form a lather with 100 cc. of the barium solution; therefore 45 cc. are equal to 12 milligrams of lime. The filtered alcoholic soap solution is diluted with dilute alcohol until the required strength is attained.

b. Degrees of hardness.—The hardness of water is expressed in degrees. In England a degree of hardness—Clark's scale—represents 1 grain calcium carbonate in a gallon of water. In Germany 1 degree of hardness represents 1 part by weight of calcium oxide in 100,000 parts by weight of water, or 1 milligram calcium oxide in 100 cc. of water. In France 1 degree of hardness represents 1 part of calcium carbonate in 100,000 parts of water, or 1 milligram calcium carbonate in 100 cc. of water. This is also known as the metric scale. In America the metric scale is coming into more general use as being preferable to Clark's scale. One degree of hardness in the metric scale represents 0.7 degree of Clark's scale, and from these data results expressed in either of these systems may readily be converted into the other.

The hardness of water is expressed as total hardness (the hardness resulting from the action of all the lime and magnesium salts present in the water) and as permanent and removable hardness. The removable hardness represents the proportion of the salts of lime and magnesium in the form of carbonates and bicarbonates. The carbon dioxid combined with the lime and magnesium in this manner is liberated by boiling the water for half an hour. The permanent hardness represents salts of lime and magnesium present in the water as sulphates, chlorids, or nitrates and is determined by applying the soap test to a part of the water that has been subjected to boiling, while the removable hardness is determined by taking the difference between the total and permanent hardness.

Process.—To determine the total hardness of water 50 cc. of the sample are placed into a glass-stoppered bottle of 125 cc. capacity and the standard solution of soap is added from a burette graduated in tenths of a cubic centimeter. The soap solution is added, at first, in amounts of about 0.5 cc., and the water agitated thoroughly after the addition of each portion of the soap solution. As soon as a slight lather begins to form the soap solution is added drop by drop, until the lather is 1 cm. in thickness and remains unchanged for five minutes. It is customary to deduct 0.2 cc. from the quantity of soap solution used in the determination as that amount is necessary to produce a permanent lather in distilled water.

Very hard waters that require more than 45 cc. of the standard soap solution, must be diluted with distilled water, because of the formation of double salts of lime and magnesium with the fatty acids in the presence of excessive amounts of these bases, and, in consequence of which, the reaction is irregular and the results unsatisfactory.

To determine the permanent hardness of water, 100 cc. of the sample are placed into a suitable vessel and boiled for half an hour, but without evaporating to dryness. After cooling the concentrated water is diluted to 100 cc. with distilled water and the hardness determined in the same manner as for the total hardness, or, if the evaporation has removed half of the water, then the whole of this may be used, if the degree of hardness is low, in making the determination of the permanent hardness.

The removable hardness of water is determined by deducting the amount of soap solution required for the permanent hardness from the amount required for the total hardness, the remainder representing the removable hardness.

Calculation of the results.—As each 0.1 cc., or measure, of the standard soap solution represents 0.25 milligrams calcium carbonate, and all the results are

expressed in terms of calcium carbonate because it is the principal agent producing the hardness of water, the calculation is very easily made. Two measures of soap solution are deducted from each reading for the end-reaction. The number of measures required $\times 0.25$ milligram calcium carbonate = the number of milligrams of calcium carbonate in 50 cc. of the water tested. This result is multiplied by 2, converting it into milligrams calcium carbonate per 100 cc. of water, or parts per 100,000, or degrees of hardness according to the metric scale. This result multiplied by 0.7 converts it into grains per gallon, or degrees of hardness of Clark's scale.

Example.—50 cc. of water required $32 - 2 = 30$ measures of soap solution. Then $30 \times 2 \times 0.25 = 15.0$ degrees of hardness according to the metric scale or $15 \times 0.7 = 10.5$ degrees of hardness of Clark's scale. This represents the total hardness of the water. 100 cc. of the same water, after being boiled down to 50 cc., required $20 - 2 = 18$ measures of soap solution. Then $18 \times 0.25 = 4.5$ degrees of permanent hardness according to the metric scale, or $4.5 \times 0.7 = 3.15$ degrees of Clark's scale. The removable hardness is determined by finding the difference in the two amounts of soap solution required for the total and permanent hardness— $60 - 18 = 42$ measures, then $42 \times 0.25 = 10.5$ degrees in the metric scale, or 7.35 degrees of Clark's scale.

Hehner's method of determining the hardness of water.—The solutions required in this method are a $n/50$ sodium carbonate solution and $n/50$ sulphuric acid. Each cubic centimeter of the standard acid exactly neutralizes 1 milligram of calcium carbonate, and each cubic centimeter of the sodium carbonate so-

lution represents a like amount of calcium carbonate, or its equivalent of magnesia, when present in a sample of water.

The sodium carbonate solution is prepared by dissolving 1.06 grams of recently ignited pure sodium carbonate in a liter of water. $1 \text{ cc.} = 1.06 \text{ milligrams sodium carbonate} = 1.0 \text{ milligram calcium carbonate.}$

The standard sulphuric acid is prepared by adding 1 cc. of pure concentrated sulphuric acid to about a liter of water. 50 cc. of the standard sodium carbonate solution is placed in a porcelain dish, heated to boiling, a few drops of indicator added (phenacetolin or lacmoid), and the sulphuric acid cautiously run in from a burette until a change of color is produced. From the result obtained the degree of dilution required for the sulphuric acid may be calculated so that 1 cc. of the sulphuric acid = 1 cc. of the sodium carbonate solution.

Process—Temporary hardness.—100 cc. of the water is tinted with 1 cc. of the indicator and heated to boiling, and the sulphuric acid cautiously added until a change of color is produced. Each cubic centimeter of acid required represents one part of calcium carbonate, or its equivalent in 100,000 parts of water, or the number of degrees of hardness according to the metric scale.

Permanent hardness.—To 100 cc. of the water is added an amount of sodium carbonate solution in excess of that required to decompose the calcium and magnesium sulphates, chlorids, and nitrates present: usually 50 cc. of the solution will be all that is required. The mixture is evaporated to dryness in a platinum dish and the residue dissolved in distilled water. The solution is filtered through a very small filter, washed, and the filtrate and washings titrated while hot with sulphuric acid. The

difference between the amount of sodium carbonate added and the sulphuric acid required for the residue, will give the permanent hardness.

If the water contains sodium or potassium carbonate there will be no permanent hardness, and there will be more acid required for the filtrate than the equivalent of the sodium carbonate added. From this excess the quantity of sodium carbonate in the water may be determined. The amount of sodium carbonate found in the water must be deducted from the result obtained for the temporary hardness.

The indicator. — The lacmoid solution is made by dissolving 2 grams of lacmoid in a liter of 50 per cent. alcohol. When the test is carried out in the cold methyl orange may be used as the indicator. It is well to use a second flask containing water colored to the same depth with the indicator for comparison, in order to determine the first change of color which marks the end-reaction.

Hehner's method is far more satisfactory than Clark's method by means of standard soap solution in testing hard waters. It is also preferable to Clark's method because it gives more definite information as to the nature of the constituents causing the hardness of water. It is customary to speak of the temporary hardness of water as determined by this method as the "alkalinity" of the water, and the permanent hardness as the "incrusting constituents" of the water, expressed in terms of calcium carbonate.

Gravimetric determination of the hardness of water.—For the more exact determination of the hardness of water the quantities of lime and magnesia present are determined gravimetrically.

Estimation of lime.—The amount of lime is determined by concentrating 50 cc. of the water through evaporation and treating the residue with ammonium chlorid, an excess of ammonium oxalate, and a small amount of ammonia. The lime is precipitated in the form of calcium oxalate while the magnesia remains in solution as magnesium oxalate. The precipitated calcium oxalate is collected on a filter, washed, dried and heated strongly, whereby it is converted into caustic lime and then weighed as such.

Estimation of magnesia.—The magnesia, which is now in the filtrate in the form of oxalate, is treated with ammonium chlorid, ammonia, and with sodium phosphate, when it is precipitated as ammonium-magnesium phosphate. The precipitate is collected on a filter, dried and fused, and is then weighed as magnesium pyrophosphate.

6. Determination of Nitrogen as Nitrates

1. Marx-Tromsdorf method.—In this method the water is titrated with indigo solution in hot acid solution. The water is mixed with an equal volume of concentrated sulphuric acid free of nitrogen, when a heat of 120° – 125° C. is generated, which favors the conversion of the nitrates into nitric acid and sulphates, causing the indigo solution to be decolorized. As soon as all the nitrates have been so changed the further addition of indigo solution will change the liquid to a yellowish-green color.

a. The indigo solution.—About 3 grams commercial indigotin are pulverized in a mortar and digested with

about 60 cc. concentrated sulphuric acid. Indigodisulpho acids are formed, besides some indigomonosulpho acids. After standing twenty-four hours the reaction is completed and the solution is poured into four times the quantity of distilled water, when, on standing, the insoluble indigomonosulpho acids are precipitated. The solution is now filtered and preserved in a glass-stoppered bottle. This solution is diluted with distilled water, before using, so that 6 to 8 cc. will be decolorized by 1 milligram of nitrogen pentoxid.

b. Standard potassium nitrate solution.—To standardize the indigo solution a solution of potassium nitrate is prepared of which 25 cc. = 1 milligram of nitrogen pentoxid (1 liter = 40 milligrams nitrogen pentoxid), but since such a small quantity cannot be weighed accurately we dissolve 7.5037 gram of potassium nitrate in a liter of water, and dilute this solution 1 : 100 before using it. 25 cc. of the dilute solution = 1 milligram of nitrogen pentoxid, and it should require from 6 to 8 cc. of the indigo solution to neutralize 25 cc. of the standard potassium nitrate solution.

Process.—It is important that the operation be carried out under the same conditions each time, especially as to the temperature of the solutions. 25 cc. of the dilute potassium nitrate solution are placed in a 100 cc. Florence flask with 25 cc. (nitrogen-free) concentrated sulphuric acid, quickly mixing them, when the temperature will rise to 120° to 125° C., and the nitrates are changed into nitric acid and sulphuric acid salts. Into this boiling solution the indigo solution is added drop by drop, at first, from a burette measuring tenths of a cubic centimeter, then in quantities of about a cubic centimeter, shaking the flask after each addition of indigo solu-

tion. Not more than 8 cc. of the indigo solution should be required. If more is required the solution is too weak. The examination of a sample of water is conducted in the same manner only that 25 cc. of the water are used instead of 25 cc. of the potassium nitrate solution. If more than 8 cc. of the indigo solution are required the water must be diluted.

Example.—For 25 cc. of potassium nitrate solution 7.5 cc. of indigo solution are required, therefore 7.5 cc. of indigo solution = 1 milligram of nitrogen pentoxid. For 25 cc. of the water 6.4 cc. of indigo solution were required, and for 1000 cc. of water $40 \times 6.4 = 256$ cc. of indigo solution, or $\frac{256}{7.5} = 34.13$ milligrams of nitrogen pentoxid in a liter of water.

2. Method of Grandval and Lajoux.—Five cc. of the water are placed in a porcelain dish of about 35 cc. capacity, two or three drops of a 1 per cent. solution of sodium carbonate added, and then evaporated to dryness on the water-bath. The steam should not be allowed to come in contact with the dish itself. The evaporation residue is treated with about 0.5 cc. of phenolsulphuric acid (made by digesting 23 grams of pure crystallized phenol in 200 cc. of pure sulphuric acid for some hours). By appropriate manipulation the acid is worked well over the bottom and sides of the dish. After some time a few cc. of distilled water are added and then a solution of caustic potash until the yellow color is well brought out. The strength of the caustic potash solution should be 10 per cent. or more. It is important that too great an excess of this reagent be not added, for if this occurs crystals of potassium sulphate are thrown down, a result which is not desirable.

A set of standards is made up for each analysis from 1, 2, 3, 4, 5, and 6 cc. of a solution of potassium nitrate, of which 1 cc. contains 0.001 milligram of nitrogen as nitrate. These portions of the potassium nitrate solution are placed in small porcelain dishes of 35 cc. capacity and treated in the same manner as described for the sample of water. (In making up the standard solution of potassium nitrate 0.7215 gram is dissolved in a liter of water, and this solution is then diluted 1 : 100 before using.)

After treating the sample of water and the standards as already described, the contents of the dishes are transferred to the long Nessler tubes of 50 cc. capacity. More distilled water is added until they are filled to within 2 or 3 cm. of the top, and the readings are then made.

3. The Schultze-Tiemann method.—By boiling with ferrous chlorid the nitrogen pentoxid is reduced to nitric oxid gas, which is measured and calculated to N_2O_5 . The reduction is as follows: $6FeCl_2 + 8HCl + K_2ON_2O_5 = 3Fe_2Cl_6 + 2NO + 4H_2O + 2KCl$. From 108 parts nitrogen pentoxid result 60 parts nitric oxid, or from 9.67689 (108×0.0896) nitrogen pentoxid result 4 liters nitric oxid; *i. e.*, 1 liter nitric oxid = 2.419 grams nitrogen pentoxid.

Apparatus required:

100 cc. flask.

Glass tubing.

Pinch-cocks.

Beaker, 30 cc. capacity.

Glass dish, 10 cm. diameter, and 5 to 6 cm. in height.

Measuring tube of 30 to 50 cc. capacity, scale divided into 1/10 cc.

A vessel somewhat higher than the measuring tube.

20 per cent. sodium hydroxid solution, boiled. Saturated solution of ferric chlorid.

Concentrated hydrochloric acid.

Sufficient water must be taken to yield 10 to 20 cc. of nitric oxid gas. This will depend on the richness of the water in nitrates.

0— 50 milligrams nitrogen pentoxid use 250 cc. water.
50—250 “ “ “ “ 100 cc. “

The water is concentrated to about 5 cc. on a water-bath, and then transferred to the 100 cc. flask and the dish washed with about 15 cc. distilled water, and this added to the water. It is not necessary to add the precipitated alkaline earths. The stopper is now put in position, and boiling commenced with both pinch-cocks open, until the quantity of water is reduced to about 10 cc., whereby all the air is removed from the apparatus. The glass tube is now inserted under the mouth of the measuring tube, which has been filled with sodium hydroxid and inverted over the dish containing the sodium hydroxid. 15 cc. ferrous chlorid solution, and 10 cc. hydrochloric acid, are now placed in the beaker. The flame is now removed and the pinch-cocks closed, so that on cooling there is negative pressure in the flask. When cooled the pinch-cock is carefully opened when the ferrous chlorid and hydrochloric acid is drawn over into the flask. Care must be taken that no air gains entrance at the same time, closing the pinch-cock before all the liquid has passed over. The flame is now again applied, heating with the pinch-cocks closed at first, until the

negative pressure in the flask is entirely removed, then the pinch-cock is carefully opened to allow the nitric oxid gas to escape into the measuring tube. Any carbon dioxid formed is absorbed by the sodium hydroxid. When no more bubbles of gas are given off the pinch-cock is closed and the flame removed, when negative pressure again develops and the remainder of the nitric oxid gas is liberated. The flame is now again applied and the pinch-cock opened to allow the gas to escape into the measuring tube. The nitric oxid gas is measured at 0° C. and 760 mm. The sodium hydroxid is allowed to cool, the cylinder is filled with boiled water, and the measuring tube is carefully transferred to the cylinder, where it is allowed to remain for several hours at room temperature. The measuring tube is raised, by means of a pair of tongs, so that the level of the water within and without the tube are the same. The temperature of the water is taken, as well as the barometric pressure and the temperature at the barometer. It must be remembered that the gas is moist and correction must be made for the increased volume due to the tension of the aqueous vapor, and deducted from the observed barometric pressure.

The reduction is made according to the following formula:

$$V_0 = \frac{V \times (b - T)}{760 \times (1 + 0.00366 \times t)}$$

T = the tension of the aqueous vapor in millimeters at the observed temperature. This must be taken from tables of tension of aqueous vapor.

4. **The aluminum method.**—A 50 cc. tube is filled with the water, and an excess (about 2 grams) of aluminum wire is added, with 2 cc. of a strong solution of sodium hydroxid free from nitrogen. It is then allowed to stand over night in a warm place, and a measured portion, usually from 2 to 10 cc., removed and made up with distilled water (free from nitrates), of the same temperature as the ammonia standards, to 50 cc., and nesslerized.

The ammonia carried off by the evolved hydrogen has frequently been caught in a trap and determined, but with 2 cc. of the caustic soda and at temperatures below 30° C., the loss will not exceed 2 per cent. in any case. Using too little caustic soda, or keeping the tubes at too low a temperature, the nitrate is not all reduced, while with the opposite conditions an appreciable amount of ammonia is carried away by the hydrogen. Taking due care as to these conditions very satisfactory results may be obtained.

In calculating the nitrate, reduction is made for the free ammonia and nitrites, but when the ammonia amounts to a considerable fraction of the total nitrogen, it is first removed by boiling with the caustic soda and thoroughly cooled before adding the aluminum. When waters do not give good colors by direct nesslerization it is necessary to distil. This can be most conveniently done indirectly by a current of steam.

Preparation of nitrate-free water.—Eight liters of ordinary distilled water are treated with 100 cc. of a 50 per cent. solution of sodium hydroxid and 5 grams

of pure aluminum foil. After some hours the water is placed in a still with 3 grams of potassium permanganate and distilled; the middle portion of the distillate is free from nitrates.

Sodium hydroxid solution.—One liter of nitrate-free water and 50 grams of the purest sodium hydroxid obtainable are brought together in a porcelain dish with about 2 grams of pure aluminum foil. When the foil is all dissolved, the solution is boiled down to a volume of 500 cc., and after being allowed to settle, filtered through asbestos. Two cc. of this solution with 50 cc. of water and 0.35 gram of aluminum foil, should indicate the presence of only a very slight amount of ammonia when treated in the same manner as samples for analysis.

7. Determination of Nitrogen as Nitrites

1. Warrington's modification of the Griess method.

—The process consists in adding to 45 cc. of the water to be tested two or three drops of hydrochloric acid (50 cc. strong acid in 50 cc. water), then 2 cc. of a saturated solution of sulphanilic acid, and finally 2 cc. of a saturated solution of naphthylamin hydrochlorid (8 grams naphthylamin, 8 cc. strong hydrochloric acid and 992 cc. of water). The presence of nitrites is indicated by the production of a most intense and beautiful rose-red color due to the formation of azobenzol-naphthylaminsulphuric acid. The rose color produced when nitrites are present is compared with the depth of color obtained from known amounts of a standard sodium nitrite solution under the same conditions. The

standards are made up from a dilute solution of sodium nitrite. 1.815 grams of sodium nitrite are dissolved in a liter of distilled water. 10 cc. of this solution are diluted to a liter with distilled water before using: 1 cc. = 0.01 milligram of nitrogen tetroxid. With this dilute solution ten standards are made up containing from 0.1 cc. to 1.0 cc. each. These standards are treated in the same manner as the sample of water, and the readings are made in the long Nessler tubes after allowing them to stand for one-quarter of an hour to permit the color to fully develop.

Water containing more than 0.002 part of nitrogen as nitrogen tetroxid per 100,000, must be diluted with a known amount of distilled water free from nitrites. Surface waters having a color above 0.1 must be decolorized by shaking with aluminum hydroxid and rapidly filtering before testing for nitrites.

2. Schuyten's method.—When 5 cc. of a 1 per cent. solution of antipyrin in acetic acid (1/10) is added to a solution containing nitrites, a green color is produced.

Antipyrin solution.—Dissolve 10 grams of antipyrin in dilute acetic acid (1 : 10), and add water sufficient to make a liter.

Process.—To 45 cc. of the sample of water in one of the long Nessler tubes, 5 cc. of the antipyrin solution are added. After standing for about half an hour the reading is made. The same standards of sodium nitrite solution may be used for comparison as in the former method. This method will show the presence of 1 part of nitrogen as NO_2 in 20,000 parts. It is therefore not as delicate as the former method but it is not hindered

by the presence of any of the ordinary contaminations in water.

8. Detection of Lead in Water

a. Method.—The presence of lead in water may be determined by taking 200 cc. of the water and precipitating the lead with acetic acid and then passing hydrogen sulphid gas through the mixture and converting it into the sulphid, the presence of lead being indicated by the black precipitate which forms. To distinguish the precipitate thus formed from the sulphid of some of the other metals, it is necessary to collect the precipitate on a filter, dissolve it in warm nitric acid, dilute with water, and then precipitate with sulphuric acid. A white precipitate forming on the addition of sulphuric acid shows the presence of lead in the water, and is now in the form of lead sulphate.

b. Colorimetric method.—The estimation of lead can be made colorimetrically if it is shown that the water contains no copper.

A solution of lead of known strength is prepared, by dissolving 0.1 gram of pure lead in excess of acetic acid and diluting with distilled water to a liter.

1 cc. = 0.0001 gram lead.

Five narrow cylinders of colorless glass are filled with

99, 97, 95, and 93 cc. water.

to which are added

1, 3, 5, and 7 cc. lead solution,

representing

1, 3, 5, and 7 milligrams lead,

in a liter of the mixture.

In a fifth cylinder is placed 100 cc. of the water acidified with a few drops of acetic acid.

To each cylinder is now added 20 cc. of freshly prepared hydrogen sulphid water, shaking well, and comparing the intensity of the brown color formed in the water with that of the cylinders of lead solution. If it compares with the cylinder containing 5 cc. of the lead solution, then 100 cc. of water contain 0.5 milligram of lead, or a liter contains 5 milligrams.

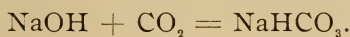
9. Detection of Zinc in Water

The presence of zinc in water may be determined by treating some of the water with ammonium sulphid, when any zinc that may be present will be precipitated as zinc sulphid. When lead and iron are also present they are likewise precipitated as sulphids, and these must be removed by boiling with sodium acetate in weak acid solution and filtering. The zinc is then recovered from the filtrate.

10. Estimation of Carbon Dioxid

1. Free carbon dioxid.—100 cc. of water are placed in an Erlenmeyer flask and 10 drops of phenolphthalein solution are added and titrated with 1/10 normal sodium hydroxid solution until the liquid is distinctly red. The titration should be repeated and nearly the entire amount of sodium hydroxid added at once, the titration being completed under constant agitation of the liquid.

1 cc. 1/10 normal sodium hydroxid = 4.4 milligrams carbon dioxid.



2. Partially combined and free carbon dioxid (Trillick's modification of Pettenkofer's method).—The free and partially combined carbon dioxid are combined by the addition of barium hydroxid, thereby precipitating the whole of the carbon dioxid, the excess of the barium hydroxid being determined by titration.

The solutions required are:

1. Barium hydroxid of the same strength as that used in carbon dioxid determination in air.

2. Barium chlorid solution 1 : 10; neutral.

3. Hydrochloric acid, of which 1 cc. = 1 milligram carbon dioxid. About 7 cc. of hydrochloric acid of 1.124 specific gravity are diluted to 1 liter with water, so that 22 cc. of the acid will neutralize 10 cc. 1/10 normal sodium hydroxid.

4. The indicator solution of phenolphthalein, or cochineal.

In a determination flask of 200 cc. capacity, closed with a rubber stopper, is placed, by means of a pipette, 100 cc. water, 45 cc. barium hydroxid, and 5 cc. barium chlorid; this is then well shaken and allowed to stand for twelve hours. Through the addition of the barium hydroxid (1) the free and half-combined carbon dioxid in the water is changed into insoluble barium carbonate; (2) the calcium carbonate in the water, being now robbed of its solving material through the operation in (1), also becomes insoluble; (3) the alkaline carbonate in the water is changed into alkaline chlorid through the action of the barium chlorid and is con-

verted into insoluble barium carbonate; (4) all the magnesium in the water is precipitated as magnesium hydroxid, and the magnesium carbonate, which is converted into insoluble barium carbonate and magnesium chlorid by the action of the barium chlorid, is precipitated finally as magnesium hydroxid; and (5) all the sulphur trioxid is combined with barium, and in place of the same the equivalent quantities of sulphur trioxid combined with bases.

The resulting precipitate contains all the carbon dioxid contained in the water in the form of barium and calcium hydroxid, and all the magnesium as hydroxid, and all the sulphur trioxid as barium sulphate.

During the sedimentation the strength of the barium hydroxid is determined by taking 100 cc. of distilled, carbon dioxid free (boiled) water, 45 cc. barium hydroxid, and 5 cc. barium chlorid solution, mixing well, and taking by means of a pipette 50 cc. ($= \frac{1}{3}$ the total amount), placing it in a flask with several drops of phenolphthalein solution, then adding the hydrochloric acid from a burette until the red color has disappeared.

After twelve hours the precipitate in the flask has become crystalline; 50 cc. are then taken of the clear supernatant solution by means of a pipette and titrated as above. The difference in the amount of hydrochloric acid required, expresses the quantity of barium required (1) to precipitate the free and half-combined carbon dioxid, and (2) to precipitate the magnesium.

The magnesium in the water must then be deter-

mined gravimetrically and by multiplication with $\frac{44}{40} = 1.1$, calculated to carbon dioxid.

If for example for 50 cc. of the mixed solution a cc. hydrochloric acid have been required, and for the water b cc., and the amount of magnesium in the water is m milligram in 100 cc., then 1 liter of water contains $[3 \times (a - b) - 1.1 \times m] \times 10$ milligrams free and half-combined carbon dioxid.

Example.—A water contains in 100 cc. 3.3 milligrams $\text{MgO} = m$.

50 cc. of the mixed solution = 12.7 cc. hydrochloric acid.
 50 cc. " " water = 7.0 cc. " "

Then 1 liter of the water contains $[3 \times (12.7 - 7.0) - 1.1 \times 3.3] \times 10$ milligrams free + combined carbon dioxid = $[3 \times 5.7 - 3.63] \times 10 = 134.7$ milligrams free and half-combined carbon dioxid.

3. Total carbon dioxid.—After the removal of the 50 cc. the sedimentation flask still contains 100 cc. and the precipitate. This remainder is now titrated with hydrochloric acid, from the amount of hydrochloric acid required is subtracted the amount required for the 100 cc. which is known from the determination of the free and half-combined carbon dioxid. The remainder is the amount of hydrochloric acid required for the precipitate which contains all the carbon dioxid and all the magnesium.

An excess of the hydrochloric acid is added (*e. g.*, 100 cc.), and the flask is placed in warm water, then in hot water, when all the carbon dioxid is driven off. Cochineal solution is now added and the solution titrated with 1/10 normal sodium hydroxid until it be-

comes red, *i. e.*, alkaline. If for the 100 cc. of solution + precipitate, d cc. hydrochloric acid were used, then $d - 2b$ cc. of hydrochloric acid were required for the precipitate alone, and 1 liter of water contains then $[(d - 2b) - 1.1 \times m] \times 10$ milligrams total carbon dioxid.

Example.—100 cc. solution + precipitate, required 43.3 cc. hydrochloric acid. 1 liter of water contains then $[(43.3 - 2 \times 7.0) - 1.1 \times 3.3] \times 10$ milligrams total carbon dioxid = $[29.3 - 3.63] \times 10 = 256.7$ milligrams total carbon dioxid.

4. Combined carbon dioxid.—100 cc. of the water are placed in an Erlenmeyer flask and 5 drops of phenolphthalein solution are added, the water is heated to boiling and titrated with hydrochloric acid (1 cc. = 1 milligram carbon dioxid) until after boiling for five minutes the decolorized liquid does not again redden.

11. Alkalies—Potassium and Sodium

The estimation of potassium and sodium is necessary only in rare instances. Usually the indirect method will suffice, wherein the potassium and sodium is estimated as sodium sulphate.

250 cc. of water are evaporated to dryness after addition of excess of sulphuric acid, the residue is incinerated to drive off the excess of sulphuric acid, then adding some ammonium carbonate and again incinerating.

The residue now contains only sulphates and silicic acid. The calcium and magnesium is calculated to sulphate, the silicic acid is added to it, and the whole

subtracted from the total weight. The remainder is sulphate of potassium and sodium, the former being expressed as sodium sulphate.

1 gram sodium sulphate = 0.437 gram sodium oxid.

12. Iron

Iron is estimated according to the following method:¹
The following are the solutions required:

1. An oxid of iron solution of known strength.—0.4306 gram pure crystalline ammonio-ferroussulphate is diluted to a liter, and some hydrochloric acid added. 1 cc. = 0.00005 gram iron, or 0.00035 gram ferrous oxid.

2. Ammonium thiocyanate solution.—7.5 grams ammonium thiocyanate dissolved in 1 liter of water.

3. Hydrochloric acid (1 : 3).—The method is based on the comparison of the intensity of the red color of a water treated with acid ammonium thiocyanate solution with the red color of a ferrous oxid solution of known strength. It is a colorimetric method.

Method.—500 cc. of water are placed in a porcelain dish, nitric acid added, and then evaporated to about 50 cc., transferred to a measuring cylinder, and diluted to 100 cc.

The liquid is now brought into a narrow cylinder of colorless glass, set on white paper, and 5 cc. of the ammonium thiocyanate solution and 1 cc. of diluted hydrochloric acid are added to it.

Besides the cylinder are placed four other cylinders

¹ A. Jolles: Arch. f. Hygiene, 8, 402.

of the same kind; into the first is placed 1, into the second 3, into the third 5, and into the fourth 7, cc. of the ferrous oxid solution. These cylinders are now filled with distilled water to 100 cc. and the color compared after several minutes with that containing the sample of water.

If its color compares with that of the fourth cylinder, there are in the 100 cc. concentrated water 7×0.00005 gram of iron, or 7×0.00035 gram ferrous oxid. This quantity of iron is contained in the 500 cc. of the water, or in a liter of the water there are 0.0007 gram or 0.7 milligram of iron, or 0.0049 gram ferrous oxid.

Quantitative estimation of iron in water.¹—A standard solution of iron is made by dissolving 0.7 gram of pure ammonia-ferrous sulphate in half a liter of water, acidulating with sulphuric acid, adding sufficient permanganate solution to convert the iron exactly into ferric salt, then diluting to a liter. Hydrogen peroxid may also be used in place of permanganate, taking care to dissipate the excess by boiling. 1 cc. of this solution contains 1/10 milligram of iron.

Process.—Evaporate 100 cc. of the water to dryness on a water-bath. Pour 1 cc. 50 per cent. nitric acid over the residue and evaporate to dryness. Dissolve the residue in 1 cc. 10 per cent. hydrochloric acid and add about 10 cc. distilled water, filter and wash through a small filter. Make up the filtrate to 50 cc. in a Nessler tube. 1 cc. nitric acid is added and then tested with 1

¹ According to Sutton's Volumetric Analysis, sixth edition, p. 194.

cc. potassium ferrocyanid solution. The presence of free acid facilitates the process.

A second Nessler tube is prepared containing 1 cc. standard iron solution, 1 cc. nitric acid, enough distilled water to fill up to the 50 cc. mark, and treated with 1 cc. potassium ferrocyanid solution. If the color in the two tubes is not the same other tubes are prepared, with more or less of the iron solution, until one is found to compare in color with that containing the sample of water.

Example.—The sample of water compared in color with a tube containing 2.5 cc. of the standard iron solution, hence it contained $2.5 \times 1/10$ milligram or $1/4$ milligram of iron in 100 cc. of the water, or 2.5 milligrams of iron per liter of the water.

13. Oxygen

The estimation of oxygen in water is made according to the method of L. M. Winkler.¹ It is based on the fact that manganous chlorid in alkaline solution is oxidized to manganic chlorid through the action of oxygen, and with the manganic chlorid an equivalent quantity of iodine is set free from an alkaline solution of potassium iodid, the iodine liberated being determined by means of a titrated solution of sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$).

The processes of the operation are as follows:

1. $\text{MnCl}_2 + 2\text{NaOH} = \text{MnO}_2\text{H}_2 + 2\text{NaCl}$
 $2\text{MnO}_2\text{H}_2 + \text{O} + \text{H}_2\text{O} = \text{Mn}_2\text{O}_6\text{H}_6$
2. $\text{Mn}_2\text{O}_6\text{H}_6 + 6\text{HCl} = \text{Mn}_2\text{Cl}_6 + 6\text{H}_2\text{O}$
 $\text{Mn}_2\text{Cl}_6 + 2\text{KI} = 2\text{MnCl}_2 + \text{I}_2 + 2\text{KCl}$
3. $\text{I}_2 + 2\text{Na}_2\text{S}_2\text{O}_3 = \text{Na}_2\text{S}_4\text{O}_6 + 2\text{NaI}$

The following solutions are required:

1. Manganous chlorid solution of 40 per cent. strength.

¹ Ber. d. chem. Ges., (1888), 2843.

2. Alkaline potassium iodid solution. 32 grams nitrogen-free potassium hydroxid dissolved in 100 cc. distilled water, to which are added 10 grams potassium iodid.

3. Concentrated hydrochloric acid.

4. 1/100 normal sodium thiosulphate solution. 2.48 grams sodium thiosulphate dissolved in a liter of distilled water.

1 cc. = 0.055825 cc. O, at 0° C. and 760 mm.

5. Starch solution as indicator.

The capacity of a glass-stoppered flask of about 500 cc. is carefully determined when filled with distilled water at 15° C. up to the stopper. This flask is then filled with the water to be examined in such a manner as to avoid bringing it too much in contact with air.

With a long pipette 4 cc. of the manganous chlorid solution and 4 cc. of the alkaline potassium iodid solution are introduced into the bottom of the flask, the stopper put in place and then the flask shaken.

The yellowish-brown precipitate is allowed to subside, and then 5 cc. of concentrated hydrochloric acid are added, the stopper replaced and the flask shaken, when the precipitate is again dissolved, but the liquid becomes brown from the iodine.

The solution of sodium thiosulphate is now placed into a burette graduated to 1/10 cc. 100 cc. of the brown liquid are taken from the flask and placed in an Erlenmeyer flask, and 2 cc. of starch solution are added when the liquid becomes bluish green. The sodium thiosulphate solution is now added from

the burette until the liquid becomes colorless. The titration is controlled by a second titration.

If the volume of the flask is a cc., then the oxygen in $(a - 8)$ cc. of water has been determined.

If 100 cc. of the liquid required b cc. of sodium thiosulphate solution, then a cc. require $\frac{a \times b}{100}$ cc. of sodium thiosulphate, or $\frac{a - 8 \times b}{100} \times 0.0558$ cc. oxygen.

This quantity was contained in $a - 8$ cc.; then a liter of water contains $\frac{1000 \times a \times b \times 0.0558}{100 \times (a - 8)}$ cc. of oxygen at 0° C. and 760 mm.

14. Phosphoric Acid

A colorimetric method for the estimation of phosphoric acid in water.¹—Since we know that the protoplasm of the cells does not consist of albumin, in the usual sense of the word, but of nucleo-proteids rich in phosphorus, and that consequently, in the decomposition of animal and vegetable excreta, we have not only nitrogenous substances but also phosphorous compounds gaining access to water.

In the method usually given for the determination of phosphoric acid in water, the water (three liters) is concentrated to a small volume, treated with nitric acid, treated with ammonium phosphomolybdate and the phosphoric acid precipitated from the water is then estimated as magnesium pyrophosphate. In this process the presence of organic matter causes the

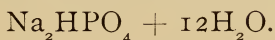
¹ Dr. Adolf Jolles : Arch. f. Hygiene, 34, 22.

result to express only from 65 to 80 per cent. of the phosphoric acid present. By evaporating the water to dryness and treating the residue with nitric acid, and again evaporating to dryness, then dissolving the residue in 10 cc. of dilute nitric acid, a much higher result is obtained than in the former process.

Jolles' method is based on the fact that small amounts of phosphoric acid salts produce a yellow color with potassium molybdate, which color is increased in intensity with increased temperature up to about 80° C., where the maximum intensity is obtained. The method is extremely sensitive and allows the detection of 0.000025 gram phosphorus pentoxid, in the cold in 20 cc. of liquid, and in warm solutions 0.0000025 gram can be detected.

Reagent.—Dissolve 8 grams chemically pure potassium molybdate in 50 cc. of water and add 50 cc. chemically pure nitric acid of 1.20 specific gravity and filter.

Solution of sodium phosphate for comparisons,



Solution A.—Fresh uncrystallized sodium phosphate, 53.23 grams, dissolved in a liter of water. This is a 1 per cent. solution. From this a series of dilute solutions are prepared.

Solution B.—10 cc. Sol. A + 90 cc. H_2O = 0.1 % P_2O_5

“ C.—10 cc. Sol. B + 90 cc. H_2O = 0.01 % P_2O_5

“ D.—10 cc. Sol. C + 90 cc. H_2O = 0.001 % P_2O_5

“ E.—10 cc. Sol. D + 90 cc. H_2O = 0.0001 % P_2O_5

10.0	cc.	Sol.	C = 0.001	per cent.	P ₂ O ₅
7.5	"	"	C = 0.00075	"	"
5.0	"	"	C = 0.0005	"	"
2.5	"	"	C = 0.00025	"	"
10.0	"	"	D = 0.0001	"	"
7.5	"	"	D = 0.000075	"	"
5.0	"	"	D = 0.00005	"	"
2.5	"	"	D = 0.000025	"	"
10.0	"	"	E = 0.00001	"	"
7.5	"	"	E = 0.0000075	"	"
5.0	"	"	E = 0.000005	"	"
2.5	"	"	E = 0.0000025	"	"

It is necessary to thoroughly remove all silicic acid from the water as it is capable of yielding a yellow color with the potassium molybdate. To accomplish this a liter of the water to be examined is evaporated to dryness in a platinum dish, the residue treated with nitric acid, and again evaporated to dryness, at 130° C., then dissolved in dilute nitric acid and again evaporated to dryness, dissolved in nitric acid and filtered. The filtrate is diluted to 20 cc., and then tested for phosphoric acid; the resulting color is compared with the sodium phosphate solution.

15. Recording the Results in Water Analyses

The results obtained in the analysis of water for sanitary purposes are recorded either according to the English system (in grains per gallon of water) or according to the metric system (in parts per 100,000 or per 1,000,000 parts of water).

The metric system is the preferable one for our purposes inasmuch as the metric system of weights and measures has been employed exclusively in the de-

scription of the various methods of analysis and in the preparation of the standard solutions.

In the different examples given under the various methods the results have always been calculated to milligrams per liter of water. With such a basis it will be easy to express the results either in parts per 100,000 or in parts per 1,000,000, since the number of milligrams per liter at once represent the parts in 1,000,000 parts of water, and, in consequence, this method of recording the results is given the preference.

If it is desired to express the results in grains per gallon this is readily done by multiplying the results in parts per 100,000 by 0.7 and the result obtained is the number of grains per gallon.

16. Interpretation of the Results in Water Analyses

The form of the most serious pollution of water is organic matter. This may be present as living organisms and the product of organic life, or the matter may be present in various stages of decomposition. It is customary to classify the condition of the organic matter by means of the condition of the nitrogenous organic matter. In this way the albuminoid ammonia is taken as an indication of the amount of undecomposed organic matter. When decomposition has begun its extent is indicated by the presence of so-called free ammonia. Further changes result in converting the free ammonia into nitrites, and finally into nitrates, the last stage in the process of alteration by which

organic matter is converted again into a form suited for assimilation by organic life.

It is imprudent to state that because a water contains unusually large amounts of any of these compounds of nitrogen that it is necessarily polluted. The signification of each compound may be stated briefly as follows, it being understood that only surface waters are now under consideration: Albuminoid ammonia was formerly considered as an indication of the presence of an equivalent amount of organic matter liable to decay, but within recent years it has been found that this is not necessarily so. The lesson to be learned from this compound is indicated most clearly by successive analyses of a water, for if the albuminoid ammonia remains unchanged for months without development of free ammonia, a comparatively large amount may be harmless. This is especially the case with brown coloring-matter which water dissolves from grasses, leaves, and roots, according to Dr. T. M. Drown, who instances the very dark water of Acushuel River, the source of New Bedford's supply, as a water containing enough albuminoid ammonia to be classified as a polluted water according to most European standards.

Free ammonia is a characteristic ingredient of sewage, but the conditions which influence its development and accumulation in natural waters are so various that one must be extremely cautious in deciding what is the signification of its presence in individual cases. It may be safely said that if an analysis shows a large amount of free ammonia in a water from a catchment area having dwellings upon it, further investiga-

tion should be made into the causes of its presence.

Nitrites are compounds of much interest, as their amount is generally found to vary less with the seasons than the other organic derivatives, and they are therefore a better index of sewage pollution. High free ammonia and high nitrites together are characteristic of recent pollution, and when they are uniformly high in a surface water they point to continuous pollution.

Nitrates indicate the complete change of organic to inorganic matter, and their importance can only be settled satisfactorily when the surface from which they were derived is known. The organic matter that is discharged into a water is rarely dangerous if it is given time to change to nitrates, but the disease germs that may have been discharged at the same time may still be a source of danger when the chemical changes are over. Chemical analysis, by indicating the amount of albuminoid and free ammonia, nitrites, and nitrates, points to the possibility of such germs being in the water and the time that has elapsed since they were discharged into it. The time is probably least when the albuminoid ammonia is high, and greatest when the nitrates are high in the analysis.

Chlorin is also a valuable indication of sewage pollution. The amount of chlorin found in natural waters varies greatly according to the proximity of the ocean, deposits of salt, or the proximity of natural gas and oil regions. In Massachusetts the chlorin content of surface waters decreases as the distance from the seashore increases. It is therefore necessary to know

always the normal chlorin content of surface waters of the locality from which the sample is derived before deciding upon the signification of the amount found in the sample analyzed. The chlorin in the reservoirs of the Boston water system has been found to vary directly with the population upon the respective watersheds. High free ammonia, high nitrites, and high chlorin are considered to afford complete proof of sewage pollution. Dr. Drown has pointed out, however, that when the chlorin is not much above the normal in waters containing high free ammonia and nitrites, the inference is that the pollution comes from farmyards or manured fields, a distinction that is often important to make.

Wanklyn gives the following rules for the interpretation of the results obtained in a water analysis: "If a water yield 0.00 part per 1,000,000 of albuminoid ammonia it may be passed as organically pure, despite much free ammonia and chlorin, and if, indeed, the albuminoid ammonia amount to 0.02, or to less than 0.05 part per 1,000,000, the water belongs to the class of pure waters. When the albuminoid ammonia amounts to 0.05 parts, then the proportion of free ammonia becomes an element in the calculation; and I should be inclined to regard with some suspicion a water yielding a considerable quantity of free ammonia, along with 0.050 part of albuminoid ammonia. Free ammonia, however, being absent or small, a water should not be condemned unless the albuminoid ammonia reaches something like 0.10 part per 1,000,000. Albuminoid ammonia above 0.10 per 1,000,000

begins to be a very suspicious sign; and over 0.15 part ought to condemn a water absolutely."

17. Limits of Impurity in Water

According to the amounts of impurity in water we may form four classes into which we classify the waters according to the degree of pollution. These classes are pure, usable, suspicious, and impure. In the following table these classes of water are given with the degrees of impurities in each.

TABLE III.

Approximate Composition of Drinking-water.

(Stated in parts per million.)

Chemical Constituents.	Pure.	Usable.	Suspicious.	Impure.
Total Solids	70.000	430.000	430.000 to 710.000	710.000
Chlorin	14.000	40.000	40.000 to 70.000	70.000
N. as Nitrates	0.140	1.120	1.200 to 2.400	2.400
N. as Nitrites	nil	nil	0.500	0.500
N. as free NH_3	0.020	0.050	0.050 to 0.100	0.100
N. as alb. NH_3	0.050	0.100	0.100 to 0.125	0.125
Organic matter	0.250	1.000	1.000 to 1.500	1.500

PART III

SOIL

I. MECHANICAL ANALYSIS

a. Collection of the Sample

In collecting a sample of soil for analysis it is important to exercise care in order that the portion collected represent, as far as possible, the average composition of the soil of the locality. The surface covering is carefully removed and then, by means of a spade, portions of equal thickness and extending to the same depth are taken up and thoroughly mixed. From the mixture obtained in this manner samples may be taken for the analysis. In instances where it is desired to ascertain the porosity and filtering capacity of the soil *in situ* a sample may be taken by means of a metal cylinder.

b. Separation of the Different Sized Grains

For hygienic purposes it is usually considered necessary to separate the soil particles into a number of groups corresponding to their size, because of the great importance of the relative proportions of the number of particles belonging to these different groups in a particular soil from the influence it would exert upon the health of the locality. The porosity and drainage capacity of a soil are almost wholly dependent upon

the relative proportions which the size of the different groups of soil particles bear to each other. A relatively large quantity of soil particles falling within the groups representing the smaller sized grains will lessen, to a considerable degree, the adaptability of such soil for a building site. Soil is damp or dry according to the preponderance of the smaller or larger sized grains making up its structure.

Sieving the soil.—The separation of the soil particles into groups according to their sizes is accomplished most readily by means of a set of sieves having meshes of different sizes. Knopp has devised a scale in which the soil particles are separated into six groups according to their size, as follows:

1st group	=	particles	coarser	than	7 mm.	=	coarse gravel.
2nd	"	=	"	ranging from	4 to 7 mm.	=	medium gravel.
3rd	"	=	"	"	2 "	=	fine gravel.
4th	"	=	"	"	1 "	=	coarse sand.
5th	"	=	"	"	0.3 "	=	medium sand.
6th	"	=	"	finer than	0.3 mm.	=	fine sand.

Process.—An average sample of the soil is taken. 1000 grams are carefully weighed, dried at 100° C., and then sieved. The quantity remaining in each of the sieves is then weighed, as follows:

Coarse gravel	=	544 grams.	Coarse sand	=	55 grams.
Medium “	=	156 grams.	Medium “	=	64 grams.
Fine “	=	90 grams.	Fine “	=	90 grams.
Total = 999 grams, loss = 1 gram.					

Elutriation.—The separation of the different sized grains of soil into groups may also be accomplished by the process known as elutriation. This is a very delicate and tedious operation and is rarely employed in the analysis of soil for hygienic purposes. This

process is more generally employed in the analysis of soil for agricultural purposes.

Knopp has devised a small apparatus for the further separation of the soil particles comprising the sixth group of his scale, those finer than 0.3 mm. in diameter. This apparatus consists of a glass cylinder 55 cm. in height which is fitted with four glass tubes with stop-cocks coming off from the side, the first at 10 cm. from the bottom, and the others 10 cm. above each other.

Process.—The soil particles forming the sixth group in the mechanical analysis described above, are placed into the apparatus. Distilled water is then added until it rises to a point 10 cm. above the highest glass tube. The contents of the cylinder are now agitated thoroughly for five minutes, then, after standing undisturbed for five minutes, the stop-cock of the upper glass tube is opened and the dirty water collected in a porcelain capsule. After again agitating the contents of the cylinder for five minutes, and allowing another five minutes for the subsidence of the coarser particles, the second stop-cock is opened and this portion of dirty water is also collected in a porcelain capsule. In like manner a third and fourth portion are collected from the third and fourth tubes. The cylinder is then again filled with distilled water, and, in like manner, the dirty water from each of the tubes collected in the capsules containing that portion previously collected from each of the tubes. The dirty water collected in each of the four porcelain capsules, as well as the portion remaining in the bottom of the apparatus, is then carefully evaporated to dryness and weighed.

2. PHYSICAL ANALYSIS OF SOIL

a. The Porosity of Soil

The porosity of a soil is dependent upon several different factors, as the looseness or compactness with

which the soil particles are packed together, the preponderance of the larger or smaller sized soil particles, and also what is known as the "separate grain structure" of the different soil particles; *i. e.*, whether they are distinctly angular or distinctly spherical in form, and the amount of gradation between these two extremes. All these factors have a direct bearing upon the amount of air and water that the soil is capable of taking up and also on the movement of the air and water within the soil. It is evident that the volume of the pores varies within wide limits in different soils.

Estimation of the porosity.—For the estimation of the porosity of soil as it occurs in nature a metallic cylinder—20 cm. in height and 5 cm. in diameter—is pressed into the soil and a corresponding portion of the soil thus removed. The bottom of the cylinder is closed with wire gauze or with a perforated metal plate. According to the formula $r^2 \times 3.14 \times h =$ the volume of soil taken is $2.5 \times 2.5 \times 3.14 \times 20 = 392.5$ cc. This same cylinder may also be used to estimate the porosity of a sample of soil taken from a mixture. It is carefully filled with the soil and well packed by tapping the cylinder on the work table. After the sample of soil has been thus carefully collected it is transferred from the cylinder to a 1000 cc. measuring cylinder containing 500 cc. of distilled water. The volume of the mixture of soil and water is then read off, and this amount deducted from the sum of the volume of soil and water employed— $500 + 392.5$ cc. = 892.5 cc. For instance, if the volume of the mixture of soil and water is 840 cc., then the volume of

the pores is 52.5 cc., or $392.5 : 52.5 :: 100 : x = 13.37$ per cent., the porosity of the soil.

Pettenkofer's method.—Another method for estimating the porosity of the soil, devised by v. Pettenkofer, consists in placing the dried soil into a glass tube 30 cm. in length, a portion 18 cm. in length having a diameter of 25 mm., and the remaining 12 cm. only 5 mm. in diameter, which is graduated at 50 cc. The narrow portion of the tube is connected below with a burette by means of rubber tubing on which is fastened a screw-clamp, the burette and rubber tubing containing distilled water. The tube is filled with the soil to be examined, up to the 50 cc. mark; then on opening the screw-clamp the water passes into the tube, and when it appears just above the column of the 50 cc. of soil in the tube the clamp is closed and the quantity of water so used is noted by reading the burette.

Calculation of the results.—50 cc. of the dry soil absorbed 9.5 cc. of water; then $50 : 9.5 :: 100 : x = 19$ per cent., the porosity of the soil.

b. Water Capacity of Soil

According to the relative size of the soil particles, and consequently the porosity of the soil, different soils take up and retain varying quantities of water. When the porosity is great the amount of water retained is small as compared with soil composed of smaller particles. The water capacity of soil is expressed in per cent. of the volume of the pores.

1. **Estimation with the metal cylinder.**—The water capacity of soil may be estimated by means of the metal cylinder used in estimating the porosity. The cylinder is weighed, and then filled with the sample of soil and again weighed. The soil is now saturated with water by holding the cylinder in a beaker of distilled water, whereby the water passes through the perforated bottom of the cylinder and gradually displaces all the air and fills the pores of the soil. As soon as the surface of the soil is covered by the water within the cylinder, and every portion of the soil has been thoroughly saturated, the cylinder is removed from the beaker and the excess of the water allowed to drain away. When the water has ceased dropping the exterior of the cylinder is carefully dried. The weight of the cylinder and moistened soil are now ascertained, when the increase in the weight of the cylinder will represent the weight of the water retained in the soil.

Example.—The porosity of the soil has been found to be 13.37 per cent.

Weight of cylinder and soil	1050	grams.
“ “ “ empty	250	grams.
“ “ the soil	800	grams.
Volume of the soil	392.5	cc.

After saturation with water—

Weight of cylinder and moistened soil	1095	grams.
“ “ “ “ dry	1050	grams.

Increase in weight of the soil 45 grams.

Therefore 800 grams, or 392.5 cc. of soil have retained 45 grams, or 45 cc. of water. The 392.5 cc. of soil, have pores equal to 52.5 cc., or 13.37 per cent. Of the 52.5 cc. of pores 45 cc. remained filled with water, or $52.5 : 45 :: 100 : x = 85.81$ cc., or 85.81 per cent. = the water capacity.

The soil may also be moistened by slowly pouring the water into the top of the cylinder until it penetrates through the soil and flows out at the bottom. The results obtained by these two methods are not exactly the same; the former method gives somewhat higher results and seems most likely to afford results that are satisfactory.

2. The Pettenkofer apparatus.—The water capacity of the soil may also be estimated by means of the Pettenkofer apparatus. After the soil has been moistened with water, as in the determination of the porosity, the reading of the burette is taken. The rubber tubing is now removed and the excess of water allowed to drain away and collected in a graduated measuring cylinder. The difference between the reading of the burette and the water drained away will represent the water capacity, or the amount of water retained in the soil.

c. The Drainage Capacity of Soil

The drainage capacity of a soil is of great hygienic importance, and, like the porosity and water capacity, is dependent upon the "separate grain structure" of the soil. It is directly dependent upon the water capacity since it represents the quantity of water that is capable of penetrating through it. The unit of measurement of the drainage capacity of soil is the amount of water that is capable of penetrating through a definite volume of clean, coarse sea gravel. If, for instance, 50 cc. of coarse sea gravel absorb 40 cc. of water, as estimated by the Pettenkofer method, of which

35 cc. drain away,—equal to 70 cc. of water for 100 cc. of gravel. The 70 cc. of water draining away from 100 cc. of gravel are represented as 1 in the comparison of the drainage capacity of any soil with coarse sea gravel, the result being expressed in decimal fractions of 1, the unit of comparison.

Example.—50 cc. of a sample of soil are placed in the glass tube of the Pettenkofer apparatus and the water allowed to pass slowly from the burette until it covers the column of soil to the extent of several centimeters, when the excess of water is allowed to flow back until it is just on a level with the surface of the column of soil. The quantity of water absorbed by the soil is then noted, indicating the porosity of the soil. The water is now allowed to drain away from the soil and is collected in a 100 cc. measuring cylinder, representing the drainage capacity of the soil, while the amount of water retained represents the water capacity. If the 50 cc. of soil used absorbed 25 cc. of water, its porosity is equal to 50 per cent. Of the 25 cc. of water absorbed 15 cc. drained away, or 30 cc. with 100 cc. of the soil. Therefore the drainage capacity is $70 : 30 :: 1 : x = 0.428$, coarse sea gravel being taken as unity.

d. Estimation of Moisture in Soil

Soil moisture is estimated by taking a known quantity of the soil, 10 or 100 grams, drying it at 100° C., and again weighing it. The loss in weight represents the amount of moisture driven off. The result is expressed in per cent. of the volume of soil taken.

e. Estimation of the Level of the Ground-water

At varying depths below the surface of the soil all the interstices are filled with water, the level of which is subject to fluctuation from various causes, as the

amount and frequency of rainfall, the proximity to streams and bodies of water either above or below the surface, the amount of evaporation that takes place from the surface, the nature of the surface covering, etc. The movement of the ground-water takes place both vertically and horizontally. Since it has been supposed that the height of the level of the ground-water influences to some extent the propagation and spreading of certain diseases, as typhoid fever and cholera, it is considered necessary for the hygienist to study the movements and fluctuations in the level of the ground-water.

The height of the level of the ground-water may be determined by ascertaining the depth at which water stands in a well, or in special borings made for the purpose. The measurement is made either by means of a long rod or a weighed tape-measure. A special apparatus devised by Pettenkofer for this purpose consists of a number of small cups fixed to a rod which is lowered into the water when the uppermost cup that contains water indicates the level of the water. Several other mechanical devices have been constructed for this purpose. The measurement must be made from a fixed point at the top of the well and the elevation of this point above the sea-level accurately determined. For purposes of comparison it is also necessary to make a number of observations on other wells or on borings in the vicinity. It is also necessary to determine the effect, upon the level of the water, of pumping water from the well for some hours.

Course of the ground-water.—The direction in which the ground-water moves is influenced by the direction in which surface streams are flowing, since, like these, it usually tends toward the sea. The direction and degree of movement which it undergoes may be determined by placing some substance in one of a series of borings and noting the direction and rapidity of the movement by computing the time required to convey the substance used to the surrounding borings in succession whereby the direction of the movement will also be indicated.

f. Estimation of the Amount of Carbon Dioxid in Soil Air

The amount of carbon dioxid in soil air is obtained by means of the Pettenkofer tube method. The absorption tube containing barium hydroxid solution of double strength is attached to the top of a driven well, by means of glass and rubber tube connections. The air is aspirated through the absorption tube by means of an aspirator. The driven wells used for this purpose consist of an iron cylinder, closed at the lower end, about 2 meters in length, which are driven into the soil. The lower end of the tube is closed with a pointed metal cap, above which are the perforations for the entrance of the soil air. The top of the tube is closed by means of a metal screw-cap. In order to procure the sample of air from the bottom of the well a glass tube is lowered into the well and held in place by a closely fitting perforated cork, so that the top of the tube is on a level with the top of the well and may be connected with the Pettenkofer absorption tube.

g. Estimation of the Soil Temperature

The soil temperature is estimated by constructing a well 3 meters in depth, lined with wood, into which a block of wood of the same size will slide easily. Attached to this sliding block of wood are several thermometers, one above the other, penetrating to definite depths of the soil. The block of wood carrying the thermometers may be so constructed as to allow its being raised and lowered by means of a weight and pulley.

PART IV

SANITARY ANALYSIS OF FOODS

CHAPTER I. MILK

Nature and composition of milk.—Milk, the secretion of the mammary glands of mammals, is an aqueous solution of casein, lactose, and small quantities of mineral matter, and holds in suspension a quantity of fat in the form of minute globules. Normal milk is an opaque, white or yellowish-white liquid, of somewhat sweetish taste, and possesses an odor resembling that of the animal from which it has been derived. The reaction of fresh milk is amphoteric; *i. e.*, it turns red litmus blue and blue litmus red. Its specific gravity ranges from 1028 to 1035.

COMPOSITION OF MILK (HIRT).

	Water	Casein	Albu- min	Total Albumin	Fat	Lactose	Salts
Human	87.09	0.63	2.35	2.48	3.90	6.04	0.49
Cow	87.41	3.01	0.75	3.41	3.66	4.82	0.70
Ewe	81.63	4.09	1.42	6.95	5.83	4.86	0.73
Ass	90.04	0.60	1.55	2.00	1.39	6.25	0.31
Mare	90.71	1.24	0.75	2.05	1.17	5.70	0.37
Goat	89.91	2.87	1.19	3.69	4.09	4.45	0.86

EXAMINATION OF MILK

a. Physical Examination

The physical examination of milk embraces the detection, through the senses, of such variations in its

character as are denoted by its appearance, taste, and odor when compared with a sample of fresh milk.

1. Specific gravity.—The specific gravity of milk varies with the temperature, the average at 15° C. being 1030; at 37.5° C., the specific gravity of the same milk is 1024. The specific gravity of milk is lowered by the addition of water, while the removal of fat raises its specific gravity, and, consequently, the normal specific gravity of good milk may be maintained by the simultaneous addition of water and the removal of fat. This is a common form of adulteration of market milk.

Determination of the specific gravity.—The specific gravity of milk may be determined by means of the lactodensimeter of Quevenne. The scale of this instrument shows the specific gravity in degrees Quevenne by using only the second and third decimal, as 32° Quevenne indicates a specific gravity of 1032.

The sample of milk is well mixed by pouring it several times from one vessel into another, or by gently agitating it for several minutes, when it is transferred to the cylinder of the instrument, filling it up to the mark near the top. The temperature of the milk is now noted with a small mercurial thermometer. The lactodensimeter is then dried and floated in the milk. When it has become quiet the eye is brought on a level with the surface of the milk and the degrees Quevenne read off on the scale, using the lower meniscus. A second, or control, observation should always be made.

The reading of the specific gravity is, however, only correct when the temperature of the milk is at 15° C. If this is not the case a correction of the reading is necessary. For each degree above 15° C., 0.2 degree Quevenne must be added to the observed reading, while a corresponding amount must be subtracted from the reading for each degree below 15° C.

The specific gravity of milk increases during the first twenty-four hours from 1 to 1.5 degrees Quevenne, and it is preferable, therefore, to place the sample of milk on ice for several hours before making the observation. The specific gravity of milk is also readily determined by means of a Westphal balance. In this determination the temperature of the milk should be, as nearly as possible, at 15° C.

2. Estimation of fat in milk.—In the examination of market milk by inspectors the fat is usually determined by means of optical methods.

a. Lactoscope.—The lactoscope of Feser is commonly employed for this purpose in Germany. The principle on which this instrument operates rests upon the fact that the degree of opacity of milk is dependent upon the percentage of fat that it contains, the higher the percentage of fat the larger the amount of water that has to be added to the milk to render it transparent.

The lactoscope consists of a glass tube 3 cm. in diameter and 17 cm. long, the lower 5 cm. of the tube being only 2.3 cm. in diameter. Within this lower portion is a cylinder of white, opaque glass on which

is a scale of six black lines. The expanded portion of the tube also bears a scale which denotes the percentage of fat in the milk. Each instrument is accompanied with a small pipette graduated at 4 cc. With this pipette 4 cc. of milk, well mixed, are transferred to the lactoscope, when the dark lines on the cylinder of opaque glass in the bottom of the tube cannot be seen. Water is now added, in small quantities, after repeated agitation, until the dark lines are just visible and can be counted when the instrument is held between the eye of the observer and a white wall. The amount of diluted milk in the tube is then read off on the larger scale, denoting the per cent. of fat in the milk.

b. Cremometer.—This instrument consists of a glass cylinder into which 150 cc. of milk are placed and allowed to stand in a warm room for twenty-four hours. The cylinder bears a scale at the top on which the amount of cream is denoted. The reading of the amount of cream is made on the scale of the instrument, each division of the scale representing one per cent. of cream when the instrument is filled to the highest mark of the scale.

These instruments are even less accurate than the lactoscope, though they afford definite knowledge, within fairly narrow limits, of the fat content of a sample of milk.

b. Chemical Analysis of Milk

1. Total solids.—10 cc. of milk are placed in a weighed porcelain crucible and carefully weighed. The milk is then evaporated to dryness in the drying

oven at 100° C. When cool the residue is weighed.

Example.—

	Grams.
Weight of empty crucible	12.73
“ “ milk and “	22.84
“ “ “ alone	10.11
“ “ residue	1.32

Per cent. of solids in the milk = 13.056

2. Ash.—The evaporation residue is carefully incinerated at a low temperature until it is fully white when the crucible is again cooled and weighed.

Example.—

	Grams.
Weight of crucible and residue	14.05
“ “ “ “ ash	12.781
“ “ ash	0.051

Per cent. of ash in the milk = 0.504

3. Fat.—

a. The Extraction Method.—About 10 grams of milk are carefully weighed in a glass or porcelain capsule and mixed with about 10 grams of freshly ignited sand, pumice stone, or asbestos, and evaporated to dryness on a water-bath.

The dish, with its contents, is then finely pulverized and transferred to a Soxhlet extraction apparatus, and the fat extracted with ether for at least five hours. The ether extract of the flask is then evaporated to dryness on a water-bath and the residue dried to constant weight (at 100° C.) and weighed. The increased weight of the flask will represent the fat in the 10 grams of milk.

b. Estimation of fat by means of the lactobutyrometer.—The method depends on the solution of the fat in ether through the action of alcohol. From the

volume of the ethereal fat solution is calculated the per cent. of fat in the milk.

Process.—The lactobutyrometer consists of a glass tube of 40 cc. capacity, closed at its lower end. 10 cc. of milk are first placed into the tube, then 10 cc. of ether (sp. gr. 0.725–0.730, at 15° C.) are added thereto. The mouth of the tube is closed with the thumb or a soft cork and the solutions gently mixed until a homogeneous mixture is obtained, carefully lifting the stopper from time to time. Now 10 cc. of 91 per cent. alcohol (sp. gr. 0.8203) are added and again agitated for several minutes, until the small clumps of casein are evenly distributed, when the tube is placed in a cylinder containing water at 40° C. After fifteen or twenty minutes, when the clear, yellowish ethereal fat solution has risen to the top of the tube, the tube is placed in a cylinder filled with water at 20° C., when further portions of fat will rise to the surface. The amount of ethereal fat solution is now noted by reading the scale of the instrument, when the per cent. of fat can be determined by reference to Table IV.

TABLE IV

Lactobutyrometer Table of Tollens and Schmidt

(From Lehmann's Handbuch)

A 1/10 cc.	B % Fat	A 1/10 cc.	B % Fat	A 1/10 cc.	B % Fat
1.0	1.339	8.0	2.767	14.5	4.093
1.5	1.441	8.5	2.869	15.0	4.195
2.0	1.543	9.0	2.971	15.5	4.297
2.5	1.645	9.5	3.073	16.0	4.399
3.0	1.747	10.0	3.175	16.5	4.501
3.5	1.849	10.5	3.277	17.0	4.628
4.0	1.951	11.0	3.379	17.5	4.792
4.5	2.053	11.5	3.481	18.0	4.956
5.0	2.155	12.0	3.583	18.5	5.129
5.5	2.257	12.5	3.685	19.0	5.306
6.0	2.359	13.0	3.787	19.5	5.483
6.5	2.461	13.5	3.889	20.0	5.660
7.0	2.563	14.0	3.991	20.5	5.837
7.5	2.665				

c. The Babcock method.—A method of determining fat in milk which is in very general use by dairymen and creameries, and which is giving very general satisfaction, is known as the Babcock method. In this method a centrifugal machine is used which is capable of making from 700 to 1200 revolutions per minute. In this method the casein is dissolved by sulphuric acid and the separation of the fat is then aided by the centrifugal apparatus. The test-bottles containing the samples of milk are revolved in a tank filled with hot water (about 95° C.). The acid and dissolved casein in the milk being heavier than the fat are thrown outward (to the bottom of the test-bottle) by the rapid motion of the machine, while the fat rises to the top and collects in the graduated neck of the test-bottle. The separation of the fat is rapid and very complete. If the whirling is carried out as soon as the acid is mixed with the milk it will not be necessary to fill the tank with hot water, as the addition of the strong acid to the milk generates enough heat to cause the fat to rise to the top.

Process.—With the graduated pipette measure off 17.6 cc. of milk and place it into the test-bottle. Great care must be exercised to have the milk and cream uniformly mixed before taking the sample. Add to the milk in the test-bottle 17.5 cc. of commercial sulphuric acid, specific gravity 1.82. If too little acid is added the casein is not all dissolved or is not all held in solution throughout the test and an imperfect separation of fat results. If too much acid is added the fat itself is attacked. After adding the acid to the milk they should be thoroughly mixed together by gently shaking with a rotary motion. There is a large amount of heat evolved on mixing the acid and milk, and the solution, at first nearly colorless,

soon changes to a very dark brown, owing to the charring of the milk-sugar and perhaps some other constituents of the milk.

As soon as the bottles have been whirled for five minutes they are filled up to the neck with hot distilled water and whirled for one minute, then filled up to the seven per cent. mark with hot water and again whirled for two minutes, after which the amount of fat is read off on the graduated neck of the test-bottle. The fat, when measured, should be warm enough to flow readily, so that the line between the acid liquid and the column of fat will quickly assume a horizontal position when the bottle is removed from the machine. Any temperature between 45° C. and 65° C. will answer, but the higher temperature is to be preferred. The slight difference in the length of the column of fat due to the difference in temperature is not sufficient to materially affect the results.

To measure the fat, take the bottle from its socket in the machine, and, holding it in a perpendicular position, with the scale on a level with the eye, observe the divisions which mark the highest and lowest limits of the fat. The difference between these gives the per cent. of fat directly. Five of the divisions on the scale on the neck of the test-bottle are equal to 1 per cent. of fat when 17.6 cc. of milk are used in the test, it being assumed that the specific gravity of the butter-fat, at the temperature at which the reading is made (about 48° C.), is 0.9. The reading can easily be taken to the half division, or to one-tenth per cent. In reading the position of the upper level of the column of fat it is important to select the point where the upper surface of the fat meets the side of the tube.

The Babcock method can also be employed to determine the fat in cream, in skim-milk, buttermilk, and in whey. In testing the fat in cream 18 cc. should be taken instead of 17.6 cc. The reason for this is that cream is lighter than milk and more of the former always adheres to the pipette. A special cream test-bottle is to be used for the purpose of making the determination. For skim-milk a test-bottle of twice the ordinary size is usually employed.

The test-bottles should always be cleaned out as soon as the reading has been recorded. If the bottles are allowed to cool before cleaning it will prove far more difficult. It is best to rinse them thoroughly with hot water, or hot water containing caustic soda solution.

d. The Leffman-Beam method.—This method is somewhat similar to the Babcock method inasmuch as the fat is separated with the aid of a centrifugal machine. In this method the casein is dissolved with 3 cc. of a mixture of equal parts of amyl alcohol and strong hydrochloric acid, and sufficient concentrated sulphuric acid to fill the bottle up to the neck.

Process.—15 cc. of a well-mixed sample of milk are placed into the test-bottle, and then 3 cc. of amyl alcohol and hydrochloric acid added and mixed; then the concentrated sulphuric acid is added and the liquids thoroughly mixed. The neck of the bottle is now filled to about the zero-point with a freshly prepared mixture of sulphuric acid and water. The bottle is placed in the centrifugal machine and whirled for one to two minutes when the amount of fat is read off on the graduated neck of the bottle.

CHAPTER II. BUTTER

Composition of Butter.—

	Per cent.
Fat	87.0
Water	11.7
Casein	0.5
Lactose + lactic acid	0.5
Mineral matter	0.3

Adulteration of Butter.—

a. By the addition of water and salt in excess.

b. By the addition of other fats, as beef, swine or

vegetable fats, as cocoanut butter, cottonseed oil, etc. For the adulteration of butter these fats must first be mixed with water so that they may resemble butter. Margarine and butterine are examples of artificial butter. Well-cleaned, melted beef-fat is allowed to solidify at 35° C. and then pressed to remove the heavy melted stearin; the oleomargarine is then treated with sour milk, coloring-matter, and oil to convert it into artificial butter.

The examination of butter includes the estimation of water, mineral matter, and testing for foreign fats.

a. Water

Into a platinum crucible are placed 5 grams of incinerated asbestos in threads, and a glass rod. This is dried at 100° C. and weighed. 10 grams of butter are now weighed accurately and placed in the crucible, melted on the water-bath; the fat is well mixed with the asbestos, and dried at 100° C. to constant weight.

b. Mineral Matter

10 grams butter are placed in a porcelain crucible, weighed and melted, and the larger part of the fat is removed by filtration by passing through a filter without ash, washing with ether. The filter is then again placed in the crucible and the residue incinerated until it is white and then weighed again.

c. Fat, Casein, and Ash

The dried residue from the water determination is treated with 76° benzine and stirred until the lumps

disappear. The contents of the dish are then transferred to a weighed crucible with the aid of a wash-bottle containing benzine, and weighed until free from fat. The contents of the crucible are now dried at 100° C. for two hours and weighed. This weight, less the weight of the crucible, represents the weight of the casein and ash. The weight of the fat is calculated from the data obtained.

The contents of the crucible are then ignited, below a red heat, and then weighed again. The loss in weight represents the casein, the remainder the mineral matter, chiefly salt.

d. Foreign Fats

The pure fat is prepared by melting butter, heating to 60° C., and filtering off the clear fat from the residue.

Milk-fat consists of a variable quantity of triglycerides of different fatty acids, of which the principal amount is the glyceride of stearic, palmitic, and oleic acids (83 to 90 per cent.); the remainder consists of glycerides of the so-called volatile fatty acids (butyric, capronic, caprylic, and caprinic).

In all other animal or vegetable fats the glycerides of the volatile fatty acids are present in quantities of 5 per cent., the milk-fat being characterized by the high proportion of combined volatile acids.

Consequently the estimation of the volatile fatty acids is the safest method to discover adulteration of the milk-fat. The Reichert-Meissl method is best adapted for this purpose.

5 grams of clear, filtered fat are placed in a round-bottomed flask of about 300 cc. capacity and carefully weighed, and 2 cc. of the sodium hydroxid solution and about 10 cc. of alcohol (96 per cent.) are added. The mixture is shaken and placed on a boiling water-bath for fifteen minutes, then the alcohol is distilled off. 100 cc. distilled water are now placed in the flask and it is again placed on the water-bath for fifteen minutes so that the soap is fully dissolved. It is essential to have the flask closed with a well-fitting cork at all times so as to exclude the carbon dioxid of the air. To the contents of the flask are now added several granules of pumice stone and 40 cc. dilute sulphuric acid of which 30 to 35 cc. = 2 cc. of the sodium hydroxid solution, and the flask connected with a condenser. The flask is heated with a small flame until the insoluble fatty acids are melted to a transparent mass, during which time (about half an hour) exactly 110 cc. have been distilled over. The distillate is now well mixed and 100 cc. filtered through a dry filter into a beaker holding 200 to 250 cc., 0.5 cc. phenolphthalein solution added, and titrated with 1/10 normal sodium hydroxid solution until a red color is produced. The number of cubic centimeters of sodium solution used should be increased by one-tenth. The Meissl degree expresses the number of cubic centimeters of 1/10 normal solution of sodium hydroxid that are required to neutralize 110 cc. of the distillate derived from 5 cc. of fat. At its lowest this is 26. The Meissl degree for animal and vegetable fat is 0.6–1.0; of cocoa-fat, 7.0

If the Meissl degree is below 26, and the fat appears otherwise normal, there is no doubt that it has been adulterated with cheaper fats.

If a = the Meissl degree then the mixture of fat contains $3.7(a - 0.6)$ per cent. milk-fat.

Example.—5 grams of fat were taken, and for 100 cc. of distillate 15.2 cc. of tenth normal sodium hydroxid solution were required, and the Meissl degree is $15.2 + 1.52 = 16.72$.

The fat was therefore not pure, but contained only $3.7(16.72 - 0.6)$ or 59.6 per cent. of milk-fat, and 40.4 per cent. of foreign fat.

e. Melting-point

The melting-point of fat can also be employed to detect adulteration.

The melted fat is drawn into a capillary glass tube which is then sealed at the lower end, the other end being attached to the bulb of a mercurial thermometer by means of a piece of rubber tubing, and then placing it into a wider cylinder containing glycerin. The latter is then warmed with a small gas flame, observing when all the fat is entirely melted, and observing the thermometer. This indicates the melting-point of the fat.

MELTING-POINT OF FATS

Milk-fat	33-37° C.
Beef-fat	41-47° C.

But since the addition of various oils may influence the melting-point of the mixture this is not a reliable method.

f. Solubility in Hot Alcohol

A more reliable method is the determination of the solubility of the fat in hot alcohol.

The fat is melted on a boiling water-bath and filtered. 5 cc. are taken and placed in a round flask of 60 cc. capacity, 20 cc. of absolute alcohol are added, and the flask set in the water-bath and boiled for two minutes. Pure butter-fat is wholly soluble in alcohol and remains clear at the room temperature longer than 120 seconds, while other fats (as suet and lard) are not easily dissolved to clear solution and become cloudy when removed from the water-bath within 60 seconds.

g. Detection of Preservatives

1. **Boric acid.**—10 grams butter are saponified in a platinum crucible with alcoholic caustic potash solution, evaporated to dryness, and incinerated. The ash is treated with hydrochloric acid and tested with curcuma paper which in the presence of boric acid, after drying at 100° C., turns red, and when treated with a solution of sodium carbonate is turned blue.

2. **Salicylic acid.**—4 cc. of 20 per cent. alcohol are placed in a test-tube and two or three drops of dilute ferric chlorid are added. To this 2 cc. of butter-fat are added and shaken. When salicylic acid is present the lower portion of the solution is colored violet.

3. **Formaldehyde.**—50 grams of butter are placed into a 250 cc. flask with 50 cc. water and melted, and then placed on a steam-bath, and 25 cc. distilled off. 10 cc. of the distillate are treated with two drops of

ammoniacal silver solution (1 gram silver nitrate dissolved in 30 cc. water and treated with ammonia until the precipitate is again dissolved, and then made up to 50 cc. with water). If formaldehyde is present it causes a black clouding to appear after standing for several hours in the dark.

CHAPTER III. MEAT AND MEAT PRODUCTS

Meat consists of the muscle fibers of the animal body which are held together by connective tissues and surrounded or interposed by fat, sinews, and bone.

The meat is of a quite variable composition, according to the portion of the body from which it is derived and the mode of fattening, the age of the animal, and other conditions. The pure muscle fiber is of less variable composition, but this does not reach the market as such.

The chemical constituents of muscle meat are, on an average,

- 75.0 per cent. water,
- 21.7 per cent. nitrogenous substances,
- 2.0 per cent. fat,
- 1.3 per cent. mineral matter.

The nitrogenous substances are muscle fiber, connective tissue, albumin, inosin, uric acid, and meat bases (kreatin, kreatinin, karnin, xanthin).

The chemical analysis of meat is made according to the general methods.

Sausage is generally preserved by the addition of saltpeter, boric acid, sodium borate, salicylic acid, or so-called preserving salt (usually a mixture of sodium

chlorid, saltpeter, and boric acid), or they are colored with anilin-red.

The examination of sausage for these preserving salts is made by taking 10 grams and boiling with 100 cc. of water and filtering.

Several drops of the filtrate are added to 5 cc. sulphuric acid containing a few crystals of diphenylamin in solution. If on shaking a blue color appears there is saltpeter present (KNO_3).

A portion of the filtrate is evaporated to dryness after adding a solution of sodium carbonate, the residue is incinerated, dissolved in hydrochloric acid, and this acid solution tested with strips of curcuma paper. If on drying the latter is colored red, boric acid is present.

The remainder of the filtrate is shaken with ether, the latter is pipetted off, and the remainder is then evaporated in a porcelain dish. The residue is dissolved in a few drops of water and tested with ferric chlorid. A violet color indicates the presence of salicylic acid.

Animal Fats

Beef-fat is pretty hard, melting only above 45°C. , and has a specific gravity of 0.859 at 100°C.

Lard is of a consistence of a salve, melting between 42° – 45°C. , and has a specific gravity of 0.860 at 100°C.

In the examination of fats they are melted to remove foreign bodies (water, salts, etc.) and then filtered and the melting-point determined.

The estimation of the specific gravity is made at 100° C. by means of a Westphal specific gravity balance, or by means of an areometer of Koenig.

Of great value in determining the purity of fats is the estimation of the *iodide degree*.

Lard is frequently adulterated with the stearates of cottonseed oil. To determine this mode of adulteration 10 cc. of the clear, melted fat are placed in a flask and 20 cc. of absolute alcohol added. This is then placed on a boiling water-bath and 2 cc. of an alcoholic-ether solution of silver nitrate added. (Beche's reagent: 1 gram silver nitrate dissolved in 200 cc. alcohol, and 40 grams ether added.)

If cottonseed oil is present a reduction of the silver nitrate takes place causing a brown color, or a precipitation of the metal, while with pure fat it remains unchanged.

CHAPTER IV. FLOUR

Examination for the Presence of Foreign Seeds

About 2 grams of the flour are placed into a test-tube and 10 cc. of acid-alcohol added (70 cc. absolute alcohol, 30 cc. water, and 5 cc. hydrochloric acid); this is slightly warmed, shaken, and the resulting color observed.

Presence of	secale cornutum (ergot)	= reddish to violet.
"	"	lolium temulentum (garlic) = { orange-red
"	"	agrostemma githago (cockle) = { to yellow.
"	"	rianthus, etc. = greenish.

Flour is sometimes adulterated with white mineral substances, gypsum, calcium carbonate, this form of

adulteration being detected by estimating the amount of ash in 10 grams of flour.

The total ash of flour does not exceed 2 per cent. (wheat flour 0.5 to 1 per cent.; rye flour 2 per cent.), in all of which 0.2 per cent. of sand is included.

The amount of sand is estimated by treating the ash of 10 grams of flour with 25 cc. of 10 per cent. hydrochloric acid, and after standing one quarter of an hour the insoluble part is filtered off, washed, dried, and weighed.

To test for coarser mineral adulteration a teaspoonful of flour is placed in a test-tube and shaken with 20 cc. of chloroform, and allowed to stand. Pure flour collects in the upper portion of the liquid; the mineral particles sink to the bottom.

CHAPTER V. VINEGAR

Vinegar should not contain less than 4 per cent. acetic acid, as experience has shown that when less is present it does not keep well. Besides acetic acid the vinegar contains alcohol and extractives, according to the raw material from which it is made, besides other constituents.

The estimation of acetic acid is made by titrating 10 cc. of vinegar with normal sodium hydroxid solution and phenolphthalein.

1 cc. normal sodium hydroxid = 0.06 gram acetic acid.

Adulteration of vinegar with free mineral acids is detected as follows: 10 cc. of vinegar are placed in a

test-tube with 3 drops of an aqueous solution of methyl violet (1 : 1000). If mineral acids are present the color changes to light blue or green.

The nature of the acid is determined as follows:

10 cc. of vinegar are treated with—

1. Barium chlorid and hydrochloric acid. A heavy white precipitate indicates the presence of sulphuric acid.

2. Silver nitrate and nitric acid. If this turns dark it indicates the presence of hydrochloric acid.

3. Calcium chloride. A white precipitate indicates the presence of oxalic acid.

It is to be remembered that a faint reaction is no indication of the presence of free acids as this may be brought about by salts in solution.

4. Nearly fill a test-tube with vinegar and sulphuric acid, one and one, being careful to pour the sulphuric acid on the vinegar, and not the vinegar on the acid; cool the mixture and add, cautiously, along the side of the test-tube, a few drops of ferrousulphate solution, so that the liquids will come in contact, but not mix; if nitric acid is present, the stratum of contact will show a purple or reddish color, which changes to brown. If the liquids are then mixed, a clear brownish purple liquid will be obtained.

The Brucine Test.—To a few cubic centimeters of vinegar in a test-tube add four or five drops of brucine and then a few drops of concentrated sulphuric acid, and if nitric acid is present, a red color will be developed.

To distinguish cider vinegar from spirit vinegar.—Place a weighed quantity of the sample to be tested in a porcelain dish, and evaporate it at a temperature of 100° C., until constant; the residuum should be, for cider vinegar, not less than 2 per cent., and should be from a clear, light brown to a dark brown color, soft, viscid, and hygroscopic; and, when burned, should give off the odor of burned apples. A lead acetate solution will cause an immediate light yellowish brown precipitate in cider vinegar, the precipitate settling, usually in flakes, in less than five minutes.

CHAPTER VI. FOOD MATERIALS CONTAINING ALKALOIDS

a. Coffee

By the term coffee we understand bean-like seeds of the fruit of the coffee-tree. The quality varies with the country in which it grows.

The unroasted beans have a yellowish green color. These are often imitated by artificial preparations, but the latter are commonly colored with ochre which is harmless.

Before using the beans are roasted, whereby their constituents are changed and the beans take on a brownish color. In the preparation of coffee as a beverage the beans are ground and an infusion made with hot water, when about 26 per cent. is dissolved.

The constituents of coffee are the alkaloid caffeine, ($C_8H_{10}N_4O_2$) acid, an ethereal oil, and the product of roasting, besides which it contains fat, albumen, mineral matter, and cellulose.

Coffee is not unfrequently adulterated by the addition of sugar-beets, chicory, yellow beets, figs, pears, cereals, malt, acorns, leguminosae, and coffee berries.

Estimation of caffein content.—5 grams coffee are finely pulverized and extracted with hot water, the infusion precipitated with neutral lead acetate solution, filtered, and the filtrate treated with hydrogen sulphid, mixed with magnesia and sand, and evaporated to dryness, the residue thoroughly extracted with chloroform. This is then evaporated to dryness, boiled with water, filtered, the filtrate evaporated *in vacuo* and in the drying oven. The resulting caffein is then also examined microscopically to determine whether it is pure or not.

Estimation of extractives.—10 grams of dry coffee are placed in a beaker with 25 cc. water. This is weighed to 0.1 gram and then warmed, boiling for fifteen minutes, preventing the loss of foam at the beginning of the boiling. After cooling, water is again added to the original weight, mixed, filtered, and the specific gravity of the filtrate determined at 15° C. by means of a Westphal balance, or a pycnometer.

By consulting Schultze's extract table, the extractive content of the solution is read off in per cent. by weight, $ab = x$, and calculate (a) the extract content, and its water content (c) according to the formula $a = x \frac{250 + c}{100 - x}$

				Per cent.
Trillich	found	the average for	chicory to be	70.7
"	"	"	" fig coffee	73.5
"	"	"	" barley coffee	65.0
"	"	"	" coffee husks only	20.0
and for true coffee about				25.0

b. Tea

The thein content of tea varies from one to three per cent.

1. Estimation of Thein.—Five grams of finely powdered tea are extracted three times, for one hour, each time with 300 cc. of water, the three extracts are mixed and concentrated to one-fourth the volume, and while hot freshly precipitated lead hydroxid is added and coarse, washed sand mixed with it. The mixture is evaporated to dryness on a water-bath and the residue is extracted with chloroform for three hours in a Soxhlet extraction apparatus. The residue which remains is dissolved in water, the filtrate placed in a porcelain dish, and evaporated on a water-bath, the residue dried at 100° C. and weighed.

2. Determination of ash.—The ash determination is of greater importance than the estimation of the thein content in determining adulteration. It should not be less than 3 per cent. nor more than 7 per cent. Of the ash only 2.5 to 4 per cent. should be soluble in water, and not more than 1 per cent. soluble in acid.

EXAMINATION OF FOOD MATERIALS FOR CHEMICAL PRESERVATIVES

The chemical preservatives most frequently employed to preserve food materials are boric, sulphurous, benzoic, and salicylic acids, and formaldehyde, either alone or in various combinations.

Boric acid and borates

Qualitative test.—The substance to be tested is rendered alkaline with milk of lime, evaporated to dryness, and incinerated. The ash is dissolved in the smallest possible quantity of concentrated hydrochloric acid, filtered, and the filtrate evaporated to dryness on the water-bath. No great loss of boric acid need be feared in this operation. The residue is moistened with a little dilute hydrochloric acid, and curcuma tincture added, and again evaporated to dryness. The presence of the least trace of boric acid is shown by the cinnabar or cherry-red color of the residue. This reaction is extremely delicate, 0.5 to 1.0 milligram of boric acid in the residue, or, for instance, 0.001 to 0.002 per cent. in milk is shown with the greatest certainty in this manner.

Concentrated hydrochloric acid also gives with curcuma tincture a red color which, however, disappears upon the addition of water, and on drying changes to brown, while the boric acid color appears only on drying and disappears only on the addition of much water, or boiling water. The red color adheres very tenaciously to the vessels but is easily removed with alcohol.

The ash, after treatment with curcuma tincture, can be used for the flame reaction by moistening it with hydrochloric acid and transferring it to the gas flame. The flame shows a green border.

Quantitative estimation.—The quantitative estimation of boric acid is quite difficult, and in the presence of sodium salts can only be carried out by expert

chemists. Traces of boric acid are widely distributed in nature, and are also contained in glass vessels and great care must be exercised in giving an opinion on this account.

Sulphurous Acids and Sulphides

Qualitative test.—The intense and characteristic odor of sulphurous acid is noticeable only on the very copious application of this agent for purposes of the preservation of food materials. If only small quantities are present the following preliminary tests are made: The material to be tested is treated with hydrochloric acid and zinc and a strip of filter-paper moistened with lead acetate is laid over the mouth of the flask containing the mixture. If a brown or black color is produced on the strip of paper one must determine whether sulphur dioxid was really present. If the paper is not colored no sulphurous acid was present. From recent observations we know that sulphurous acid results from the fermentation of different substances, from the reduction of sulphates or from albuminous substances, and the simple qualitative determination of the presence of sulphurous acid or its salts does not show that it was added as a preservative.

Quantitative estimation.—For this purpose 200 cc. of beer or wine, for instance, are treated with 5 cc. of phosphoric acid, placed in a retort or distillation flask attached to a Liebig's condenser, and 100 cc. are distilled off. The condensation tube must be conducted into 20 cc. of tenth normal iodine solution. It is rec-

ommended to carry out the procedure by conducting a continuous stream of carbon dioxide gas washed in water, through the distillation flask; one prevents in this manner the return of the distillate on cooling off the distillation flask. The iodine solution should not be entirely decolorized. The iodine converts the sulphurous acid into sulphuric acid ($\text{SO}_2 + 2\text{H}_2\text{O} + 2\text{I} = \text{H}_2\text{SO}_4 + 2\text{HI}$), which, after acidulation with hydrochloric acid, can be precipitated with barium chloride and weighed as barium sulphate. 1 milligram barium sulphate represents 0.2748 milligram sulphur dioxide.

Salicylic Acid and Salicylates

Qualitative test.—If salicylic acid is plentifully present it is easily detected; 50 cc. of the liquid, beer or wine for instance, are acidulated with sulphuric acid, shaken with 50 cc. of equal parts of ether and petroleum ether and the clear ether extract filtered. The ether and petroleum ether in the filtrate are fully removed and to the remaining liquid a few drops of highly diluted neutral ferric chloride solution are added. A violet color indicates the presence of salicylic acid; the intensity of the color is indicative of the quantity present.

Detection of salicylic acid in milk and butter.—100 cc. of milk are diluted with 100 cc. of distilled water of 60° C., and precipitated with 8 drops of acetic acid and 8 drops of a solution of mercuric oxide in nitric acid, shaken and filtered. The filtrate is shaken with 50 cc. of ether which takes up the salicylic acid. Butter is first treated with sodium carbonate by making a

homogeneous mixture, and then proceeding as in testing wine or beer.

Benzoic Acid and Benzoates

Quantitative test of Meissl.—The substance to be examined is mixed with barium hydroxid and evaporated to dryness on a water-bath (milk is first mixed with clean sand). The residue is then acidulated with sulphuric acid and shaken three to four times with cold 50 per cent. alcohol. For the removal of milk-sugar and salts it is necessary to treat with barium hydroxid, evaporate to dryness, acidulate with sulphuric acid, and then extract the benzoic acid with ether. The ether is evaporated under 60° C., when the benzoic acid crystallizes out. Dissolved in water, benzoic acid gives a beautiful reddish yellow color with dilute, neutral ferric chlorid solution.

PART V

VENTILATION AND HEATING

CHAPTER I. VENTILATION

a. Natural ventilation.—The study of the interchange between the inside and outside air in the ventilation of rooms and buildings may be made in several different ways. The most common method is that devised by Pettenkofer. This method consists in generating carbon dioxid in a closed room, by burning candles, or by the action of acids on carbonates, mixing it thoroughly with the room air, and then determining the rate at which the carbon dioxid in the air diminishes through the interchange between the inside and outside air. The proportion of carbon dioxid in the room air and in the outside air is first determined, then, after generating the carbon dioxid, examinations of the air are made, at intervals of fifteen minutes, during one or several hours. The quantity of the incoming air, or the amount of ventilation, is then calculated by means of Seidel's formula :

$$x = 2.303 \times m \times \log \frac{p_1 - a}{p_2 - a} \text{ cubic meters ;}$$

where m = the cubic content of the room in cubic meters,

p_1 = carbon dioxid in room air at beginning of observation,

p_2 = carbon dioxid in room air at end of observation,

a = carbon dioxid in outside air,

x = quantity of incoming air.

b. Artificial ventilation.—To determine the interchange brought about between the room air and the outside air through artificial ventilation we measure the velocity of the current of the incoming air as it issues from the ventilator openings, or as it passes out through the exit openings. This is done by means of an anemometer.

Anemometers are of two kinds: (1) dynamic anemometers, in which the air current sets in motion a small wheel whose motion is communicated by means of clock-work to a set of dials on which the velocity of the air current is recorded in meters; and (2) static anemometers, in which the air current is measured by the pressure which it exerts on a thin sheet of metal which is connected with a scale on which the degree of deflection from the zero-point denotes the rate of movement.

Each anemometer should be tested first as to the degree of its efficiency. It requires a definite velocity of current to start the wheel of a dynamic anemometer, and this factor is different for each instrument. Usually the necessary calculations for the correction of these instruments have been determined by the maker—therefore it is not necessary to go into the details of the operation.

Process.—A reading of the dials of the anemometer is made when it is placed in the ventilator opening for one minute and another reading taken. The difference between the two readings will indicate the velocity of the

air current in sixty seconds, or divided by sixty, will indicate the velocity of the current per second. The result is expressed in meters per second.

It is not sufficient to make a single observation at the center of the ventilator opening as the velocity of the air current there is greater than at any other point. Usually an observation is made at the center and at each of the four corners of a rectangular opening, or at least two of the opposite corners besides the center, and then taking the mean of all the observations. Similar observations must be made at all the ventilator openings in a room if more than one exists, to ascertain the total amount of the incoming air. The amount of ventilation may also be determined by making similar observations on the exit openings of the ventilators as to the amount of air leaving the room.

In order to determine the amount of natural ventilation we find the cubic content of the room—the cubic space—by multiplying the length, width, and height of the room in meters, together. We also determine the area of the ventilator openings.

Example.—A room measuring 5 meters long, 3 meters wide, and 4 meters high = 60 cubic meters = the cubic content. (Ordinarily it is not necessary to make any deduction from the cubic content of a room on account of the furniture nor any additions for the recesses of windows and doors, since the corrections would make very little change in the result.) The ventilator opening is circular in shape and 48 cm. in diameter, or 24 cm. radius—then it is $24 \times 24 \times 3.14 = 1808.64$ sq. cm. = 0.180864 sq. m. in area.

The velocity of the incoming air current is as follows :
In one minute—

	Meter.
At the center of the circle	= 0.7386
“ “ lower margin	= 0.6700
“ “ upper “	= 0.7200
“ “ right “	= 0.7480
“ “ left “	= 0.7500

or $3.6266 \div 5 = 0.7253$ meter per second. The volume of air entering each second is found by multiplying the area of the opening by the velocity of the current— $0.1808 \times 0.7253 = 0.131134$ cubic meter per second, or 472.08 cubic meters per hour. The dimensions of the room are $5 \times 4 \times 3$ meters = 60 cubic meters, the cubic content, and it requires, therefore, $60 \div 7.868$ (the velocity per minute) = 7.62 minutes to change the air of the room, or the air is changed nearly eight times each hour.

CHAPTER II. HEATING

The investigation of the warming of a building should include the following:

- a. The extent of the combustion.
 - b. The heating effect produced in different parts of the building.
 - c. The possibility of any detrimental effect on health.
1. The study of the extent of the combustion comprises :
 - a. The chemical analysis of the combustion materials in order to estimate the theoretical amount of heat it can yield.
 - b. The estimation by means of a calorimeter of the amount of heat passing off as water, expressed in calories.

By calorie is meant the amount of heat necessary to raise the temperature of a liter of water 1° C.

- c.* The estimation by means of a pyrometer, of the temperature of the air entering and leaving the heater.
- d.* The estimation of the volume, the temperature, and the chemical composition of the smoke. The volume of smoke is estimated by measuring the size of the chimney and the rapidity of current of smoke passing out of it. The temperature is measured by means of a pyrometer or air-thermometer.

The determination of the chemical composition of the smoke is made through gas analysis—though it usually consists of carbon dioxid, nitrogen, and oxygen, with the addition of carbon, watery vapor, though carbon monoxid is also frequently present, and is detected by means of palladium chlorid solution. In the absence of carbon monoxid the estimation of the carbon dioxid and oxygen usually suffices.

2. The estimation of the heating effect on the different rooms requires the determination of

- a.* The temperature.
- b.* The humidity, especially the deficiency of saturation.
- c.* The cubic contents of the rooms.
- d.* The amount of natural ventilation.

3. The determination of the possibility of any detrimental effect upon the health of the occupants is

not very readily determined. We may determine the presence or absence of carbon monoxid, the temperature of the room, the humidity of the atmosphere, and in this manner derive some information as to the healthfulness of the room.

INDEX.

Acid, boric, in butter.....	137
hydrochloric	60
nitric	68
nitrous	68
phosphoric	68, 106
salicylic, in butter.....	138
silicic.....	67
sulphurous.....	60, 68
Air, atmospheric.....	6
chemical analysis of	41
Pettenkofer flask method.....	45
tube method.....	53
collection of samples of	49
impurities in	41
gaseous	41
solid	41
moisture in.....	23
movements, qualitative estimation of	34
quantitative estimation of	35
physical examination of.....	7
soil	123
volume, reduction of.....	53
water capacity of	28
Aitken's dust counter.....	59
Alkalies in water	101
Alkaloids, food material containing	143
Aluminum method for nitrates.....	93
Ammonia in air	61
qualtitative test	61
quantitative test.....	61
gravimetric method.....	61
volumetric method	62
Ammonia in water	70
free and albuminoid.....	74
Ammonia-free water, collection of.....	75
Analysis of air, chemical	41
foods, sanitary.....	125
milk, chemical.....	128
physical	125
soil, mechanical.....	114
water, sanitary....	64
Anemometer.....	37, 151
Animal fats, examination of	140
Aqueous vapor, estimation of, in air	23, 30, 54
tension of	22, 26

Ash in butter	134
milk	129
tea.	145
Atmometer, Pische's	32
Atmospheric air ..	6
pressure	15
Babcock's method	131
Barometer	17, 49
aneroid	22
manner and place of hanging	19
mercurial	17
cistern	17
differential	21
stationary	21
scale	18
Barometric pressure, correction for	8, 20, 28
Bellows, hand	42
Benzoic acid and benzoates in food	146
Beaufort's scale of air movements	36
Boiling-point of water	7
Regnault's table	10
Boric acid in butter	137
and borates in food	146
Bottles, glass-stoppered	49
Brucine test in vinegar	143
Burette, Bunte gas	42
Mohr's	49
reading of	51
Butter, adulteration of	133
casein in	134
composition of	133
detection of preservatives in	137
melting-point of	136
mineral matter in	134
solubility of, in hot alcohol	137
Caffein, estimation of, in coffee	144
Calcium	69
Carbon dioxid	44, 67, 97, 98, 100, 101
qualitative estimation of, in air	44
quantitative estimation of, in air	45
monoxid, qualitative tests	56
chemical tests	57
spectroscopic method	56
Casein in butter	134
Casserole, cleansing of	78
Centigrade scale	14
Chemical analysis of air	41
milk	128
preservatives in food	146
water	67

Chlorin	66, 68, 71
Cleansing the casserole	78
Clearness of water	65
Clouds, designation of amount of	39
estimation of amount of	38
Coffee	143
Collection of sample of air	49
soil	114
water	64
Color of water	66
Copper in water	70
Corrections of barometric readings	8, 20, 53
Cremometer	128
Data on the label	65
Deficiency of saturation	23
Degrees of hardness, Clark's scale	82
Metric scale	82
Dew-point	22
Drinking-water, approximate composition of	113
Dust counter, Aitken's	59
Dust in air, estimation of, by weight	58
Dust particles	59
Elutriation of soil	115
Estimation of moisture in air	23, 30
thein in tea	145
Evaporimeter	31
Extractives, estimation of, in coffee	144
Fahrenheit scale	14
Fat in butter	134
milk, estimation of	127, 129
Babcock method	131
by means of lactobutyrometer	129
extraction method	129
Leffman-Beam method	133
Fats, animal	140
foreign, in butter	135
Florence flask	49
Flour	140
Fog	38
Food materials containing alkaloids	143
Foods, sanitary analysis of	125
Foreign fats in butter	135
Formaldehyde in butter	138
Gaseous impurities in air	41
Hail	33
Hand bellows	48
Hardness of water	80
permanent	85
temporary	85

Heating, testing efficiency of	153
Hehner's method for hardness of water.....	84
Humidity of the atmosphere.....	23
absolute	22
relative.....	22
calculation of.....	30
Hydrochloric acid, qualitative test	60
quantitative test	60
Hydrogen sulphid	54, 67
Hygrometers	24
direct	24
Daniell's.....	24
Dines's.....	24
Regnault's	24
indirect	25
hair	25
wet- and dry-bulb thermometer.....	25
Hygroscope.....	31
Hypsometer	7
Impurities in air, gaseous.....	41
solid.....	41
ammonium thiocyanate.....	73, 75
water, limits of.....	113
Indicators, lacmoid	86
phenolphthalein	48
potassium chromate	72
rosolic acid.....	47
Indigo solution	77
Interpretation of results in water analyses	109
Iron in water	69
quantitative estimation of.....	102, 103
Knopp's elutriator.....	116
Lactobutyrometer	129
table	130
Lactoscope	127
Lead, in water, detection of	69, 96
colorimetric method.....	96
Leffman-Beam method	133
Lime, estimation of	69, 87
Limits of impurity in water.....	113
Magnesia, estimation of	69, 87
Manometer, dynamic.....	34
Marx-Tromsdorf method for nitrates	87
Materials, food, containing alkaloids.....	143
Maximum of saturation	23
Meat and meat products.....	138
Mechanical analysis of soil.....	114
Melting-point of butter	136
Metals, heavy, in water	69

Meteorology	7
Milk, chemical analysis of.....	128
ash.....	129
fat	129
total solids	128
estimation of fat in.....	127
lactoscope	127
cremometer.....	128
examination of.....	125
nature and composition of.....	125
physical examination of	125
specific gravity of	126
Mineral matter in butter.....	134
Moisture, in air, estimation of	23
by chemical methods.....	30
evaporation of, from the earth's surface.....	31
precipitation of	32
in soil, estimation of.....	121
Nitric acid.....	68
Nitrogen as nitrates, determination of.....	87
aluminum method.....	93
Marx-Tromsdorf method.....	87
method of Grandval and Lajoux	89
Schultze-Tiemann method.....	90
nitrites, determination for.....	94
Schuyten's method	95
Warrington's modification of Griess' method	94
Nitrous acid	68
Observation of temperature.....	7
Odor of water.....	66
Organic matter.....	58
determination of, Remsen's method.....	58
nitrogenous.....	58
oxidizable	58, 78
Oxygen	42, 104
Phosphoric acid.....	68, 106
Pipettes	49
Potassium	69, 101
Precipitation of moisture	32
Preservatives, detection of, in butter	138
Pressure, atmospheric.....	15
Psychrometer	25
sling	26
Pyrometer.....	11
Radiation, solar, measurement of.....	13
terrestrial	13
Rain	32
Rain-gauge.....	32

Rain-gauge, position of	33
Reaction of water	66
Reading of barometer	17
Réaumur scale	14
Recording results in water analyses	108
Residue, incineration of	71
Results, calculation of	53, 83
interpretation of	109
representation of	39
Salicylic acid in butter	138
food	149
Salts in solution in water	67
Sanitary analysis of food	125
water	64
Saturation, deficiency of	23
maximum of	23
Scales, thermometer	14
Schultze-Tiemann method, for nitrates	90
Silicic acid	67
Sleet	33
Snow	33
Soap solution, standard	81
Sodium	69, 101
Soil air, estimation of carbon dioxid in	123
mechanical analysis of	114
elutriation of	115
sieving of	115
physical analysis of	116
drainage capacity of	120
estimation of level of ground-water in	121
moisture in	121
porosity of	116, 117
Pettenkofer's method	118
water capacity of	118, 119
Pettenkofer's apparatus	120
Solar radiation	13
Solid impurities in air	41
Solids, total, in water	70
Solubility, in hot alcohol, of butter	138
Solutions, standard :	
alkaline potassium iodid	105
permanganate	75
ammonium chlorid	75
ammonioferric alum	73
ammonium thiocyanate	102
antipyrin	95
barium hydroxid	46
hydrochloric acid	102, 105
iodin	55
manganous chlorid	104

Solutions, standard :

Nessler's reagent.....	75
nitric acid.....	72
oxalic acid.....	45, 73
oxid of iron	108
potassium nitrate	88
permanganate.....	78
silver nitrate	71, 74
soap	81
sodium chlorid.....	72, 74
hydroxid	94
phosphate	107
thiosulphate	55, 105
starch.....	55, 105
sulphuric acid.....	78
standardizing of	79
titration of	51
Sulphurous acid, qualitative test.....	60, 68, 148
quantitative test.....	60, 148
Taste of water	66
Tea	146
Temperature, observation of	7
at barometer.....	19
of soil.....	124
Thein in tea, estimation of	146
Thermograph.....	11
Thermometers.....	7, 48
for high temperatures	10
maximum-minimum	11
mercurial	7
scale	14
special	10
spirit.....	10
Vapor, aqueous	23, 30, 54
tension of	22, 26
Ventilation, testing efficiency of	151
artificial.....	152
natural.....	151
Vernier	18
Vinegar, cider	144
spirit.....	144
Water,	63
ammonia-free.....	75
chemical analysis of.....	67
qualitative	67
quantitative.....	70
composition of.....	65
clearness of.....	63

Water, collection of sample of	64
color of	66
drinking-, approximate composition of	113
ground-, course of	123
height of	121
hardness of	80
Clark's method	82
Hehner's method	84
gravimetric determination of	86
nature and composition of	63
nitrate-free	93
odor of	66
physical examination of	65
properties of	63
reaction of	66
sanitary analysis of	64
taste of	66
Weather prognostication	39
Wind, force, rapidity, and direction of	34
Wind vane	34, 37
Zero-point, control of	7
Zinc in water, detection of	70, 97

ERRATA.

On page 16, 3d line from bottom, for "higher" read "lower."

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